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PARAMETRIC COST STUDIES PERTAINING TO DUAL-PURPOSE POWER AND WATER DESALINATION PLANTS

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FOREWORD

This is the one-hundred and ninth of a series of reports designed to present accounts of progress in saline water conversion with the expectation that the exchange of such data will contribute to the long-range development of economical processes applicable to large-scale, low-cost demineralization of sea or other saline water.

Except for minor editing, the data herein are as contained in the reports submitted by Burns and Roe, Inc. under Contract No. 14-01-0001-345, covering engineering studies completed in December 1963. The data and conclusions given in this report are essentially those of the Contractor and are not necessarily endorsed by the Department of the Interior.

Created in 1849, the Department of the Interior--America's Department of Natural Resources--is concerned with the management, conservation, and development of the Nation's water, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

As the Nation's principal conservation agency, the Department of the Interior works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States--now and in the future.

TABLE OF CONTENTS

		Page
I.	Introduction	1
II.	Summary	2
	A. Water and Power Production Combination	2
	B. Computer Optimization	2
	C. Results	4
III.	Discussion	19
	A. Selection of Reactor Type and Steam Conditions	19
	B. Nuclear Island Capital Costs	22
	C. Fuel Costs	24
	D. Operation, Maintenance and Insurance Costs	24
	E. Turbine Plant	27
	1. Choice of Cycles and Heat Balances	27
	a. Nuclear Plants	32
	b. Fossil Fuel Plants	54
	c. Auxiliary Power	56
	d. Cost Estimates	57
	F. Desalination Plant	59
	1. Description	59
	2. Computer Runs	64
	a. Cases Considered	64
	b. Conditions Used	66
	3. Computer Results	66
	4. Capital Cost Curves	71
	5. Performance Ratio Curves	75
	6. Cross Plots	75
	G. Unit Cost Calculations	75
	1. Steam Costs	87
	a. Nuclear Steam Costs	87
	b. Fossil-Fuel Steam Costs	90
	2. Costs of Electricity	90

TABLE OF CONTENTS (cont)

		Page
3.	Cost of Water Desalination	94
	a. Capital Investment	94
	b. Operating Costs	97

APPENDIXES

A-1	References	101
A-2	Curves	102

LIST OF TABLES

1.	Summary of Results - 250° F Brine Temperature	6
2.	Summary of Results - 350° F Brine Temperature	7
3.	Summary of Cases and Performance Data - Nuclear Pressurized-Water Reactor Plants	47
4.	Summary of Cases and Performance Data - Fossil-Fuel Plants	55
5.	Capital Costs for Pumping Installations	58
6.	Site Costs	60
7.	Nuclear Reactor Plant Cost Estimates	61
8.	Fossil Plants Cost Estimates	62
9.	Combinations of Independent Parameters for Computer Runs	67
10.	Input Data - Constant for All Runs	68
11.	Variable Input Data	69
12.	Summary of Economic Data for Optimum Water Plants from Representative Computer Runs	70
13.	Steam Generation Costs - Nuclear Plants	88
14.	Steam Generation Costs - Fossil-Fueled Plants	91
15.	Electric Power Generation Costs - Nuclear Plants	92
16.	Electric Power Generation Costs - Fossil-Fueled Plants	93

LIST OF TABLES (cont)

		Page
17.	Water Desalination Plant - Capital Investment Costs	95
18.	Cost of Desalinated Water	98

LIST OF ILLUSTRATIONS

1.	Available and Required Steam vs. Reactor Power and Water Production	3
2.	Combined Nuclear Power Plant and Water Desalination Plant - Capital Cost of Desalination Plant vs. Water Production (250° F Brine Temperature)	9
3.	Combined Nuclear Power Plant and Water Desalination Plant - Steam Cost @ Steam Generator vs. Reactor Power Level	10
4.	Combined Nuclear Power Plant and Water Desalination Plant - Electric Power Cost vs. Reactor Power Level	11
5.	Combined Nuclear Power Plant and Water Desalination Plant - Water Unit Costs vs. Water Production (250° F Brine Temperature)	13
6.	Combined Nuclear Power Plant and Water Desalination Plant - Combination of Cost Factors (250° F Brine Temperature)	14
7.	Combined Fossil-Fueled Power Plant and Water Desalination Plant - Steam Cost @ Steam Generator vs. Boiler Power Level	15
8.	Combined Fossil-Fueled Power Plant and Water Desalination Plant - Electric Power Cost vs. Boiler Power Level	16
9.	Combined Fossil-Fueled Power Plant and Water Desalination Plant - Water Unit Costs vs. Water Production (250° F Brine Temperature)	17
10.	Single-Purpose Water Desalination Plant Fossil-Fueled Boiler - Boiler Power Level vs. Water Production	18

LIST OF ILLUSTRATIONS (cont)

		Page
11.	Pressurized-Water Reactor Typical Flow Diagram - Primary System	21
12.	Nuclear Power Plant Capital Cost	23
13.	Nuclear Power Plant Fuel Costs	25
14.	Annual Operating and Maintenance Costs	26
15.	Annual Cost of Maintenance Materials and Operating Supplies	28
16.	Gas-Fired Steam Plant Annual Operating and Maintenance Costs	29
17.	Nuclear Liability Insurance Annual Premium	30
18.	Nuclear Liability Insurance Financial Protection Requirements	31
19.	Power Requirements for Water Desalination Plants	33
20.	Heat Balance - Case 1	34
21.	Heat Balance - Case 2	35
22.	Heat Balance - Case 3	36
23.	Heat Balance - Case 4	37
24.	Heat Balance - Case 5	38
25.	Heat Balance - Case 6	39
26.	Heat Balance - Case 7	40
27.	Heat Balance - Case 8	41
28.	Heat Balance - Case 9	42
29.	Heat Balance - Case 10	43
30.	Heat Balance - Case 11	44
31.	Heat Balance - Case 12	45
32.	Heat Balance - Case 15	48
33.	Heat Balance - Case 16	49
34.	Heat Balance - Case 17	50
35.	Heat Balance - Case 18	51
36.	Heat Balance - Case 19	52
37.	Heat Balance - Case 20	53

LIST OF ILLUSTRATIONS (cont)

		Page
38.	Desalination Plant Flow Chart	65
39.	Cost of Concrete Stages, Flash Evaporation Desalination Plant	72
40.	Desalination Plant Cost, Principal Items of Equipment - 250° F Brine Temperature	73
41.	Desalination Plant Cost, Principal Items of Equipment - 350° F Brine Temperature	74
42.	Performance Ratio vs. Production Rate - Power Cost of 3 Mills/KWHR	76
43.	Performance Ratio vs. Production Rate - Power Cost of 6.5 Mills/KWHR	77
44.	Performance Ratio vs. Production Rate - Power Cost of 10 Mills/KWHR	78
45.	Performance Ratio vs. Steam Cost - 1 MMGPD Production	79
46.	Performance Ratio vs. Steam Cost - 5 MMGPD Production	80
47.	Performance Ratio vs. Steam Cost - 8 MMGPD Production	81
48.	Performance Ratio vs. Steam Cost - 17 MMGPD Production	82
49.	Performance Ratio vs. Steam Cost - 20 MMGPD Production	83
50.	Performance Ratio vs. Steam Cost - 35 MMGPD Production	84
51.	Performance Ratio vs. Steam Cost - 50 MMGPD Production	85
52.	Performance Ratio vs. Steam Cost - 54.5 MMGPD Production	86
A-1	Nuclear Power Plant Capital Costs	102
A-2	Nuclear Power Plant Fuel Costs	103

I. INTRODUCTION

This report contains the results of an optimization study conducted in the general field of design and economics of dual-purpose water desalination plants. Specifically the study concerned itself with investigation of the following items:

A. Determination of the design and cost of dual-purpose saline water conversion plants producing potable water at minimum cost and electric power as a by-product. Water and power production costs were determined, for multistage flash saline water conversion plants from 7,000,000 to 50,000,000 gallons-per-day capacity, in conjunction with electric power generators driven by steam from nuclear reactors of 40-, 70-, 120- and 500-megawatt thermal power levels. Municipal financing rates were used and brine heater temperatures of 250° F and 350° F were considered. Electric power was considered to be sold at production cost.

B. Determination of the minimum cost of production of potable water from sea water in a multistage flash evaporation plant, without by-product power production, using a 40-MWt nuclear reactor as the energy source.

C. Determination of the minimum cost of production of potable water from sea water in multistage flash evaporation plants ranging from 1,000,000 to 14,000,000 gallons per day, without by-product power production, using fossil fuel as the energy source. Fossil fuel costs of 20, 30 and 40 cents per million Btu were considered.

II. SUMMARY

A. Water and Power Production Combinations

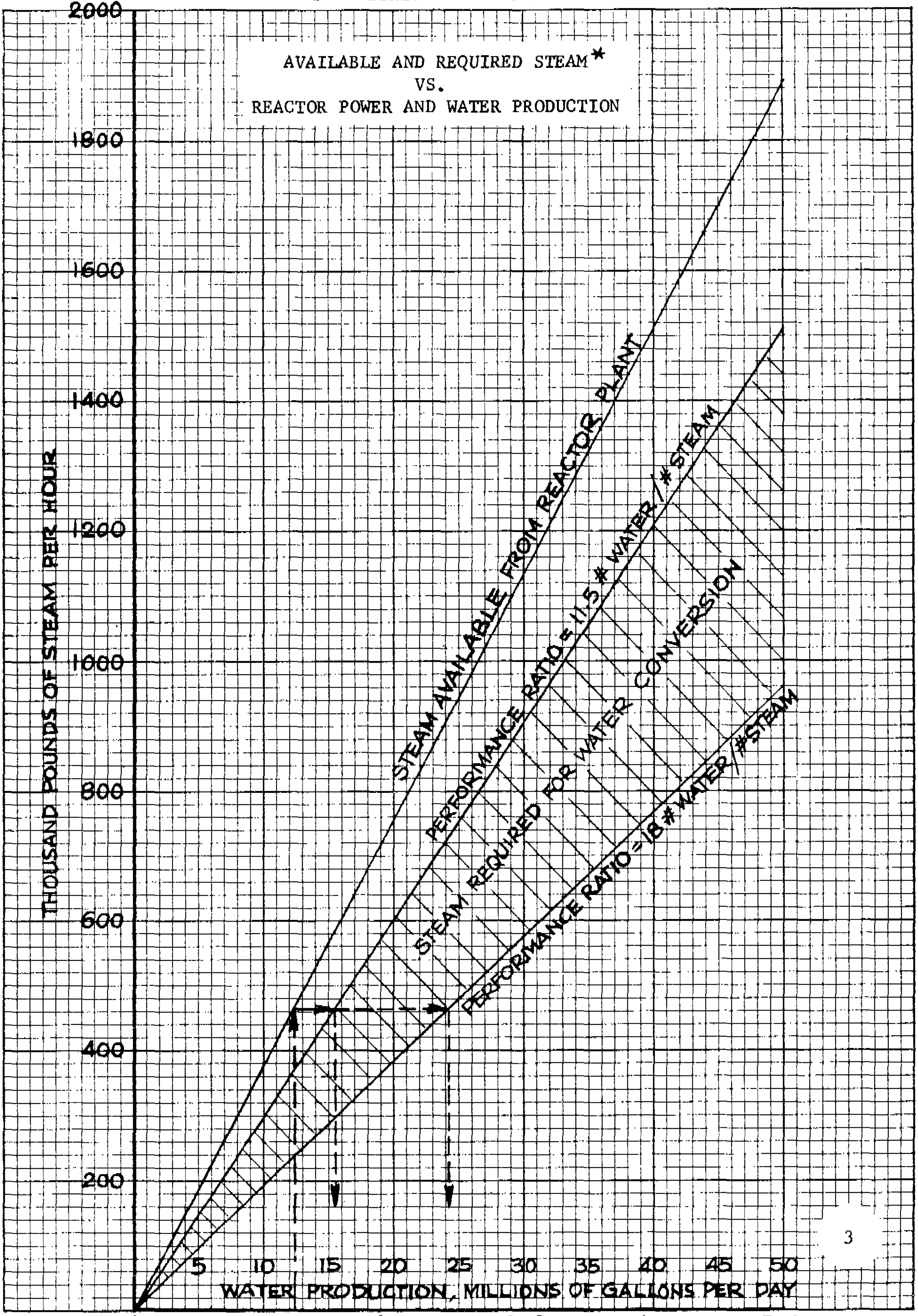
Initial calculations of the steam available from the reactor plants in the sizes 40-, 70-, 120- and 500-MWt and also the steam required for desalination water, based on reasonable estimates of performance ratios, indicated that only certain combinations would be technically and economically feasible. The results of these calculations are shown in Figure 1. As can be seen from Figure 1, certain combinations of reactor power levels and water production would not be possible. For example, at a reactor power level of 120 mw, the water production capacity must be about 23,000,000 gallons per day (mmgpd) or less. Using this chart as a basis the following combinations were selected as the representative of possible dual-purpose plants:

Reactor Power Level	Water Production
40 MWt	$\simeq$ 7 mmgpd
70 MWt	$\simeq$ 12 mmgpd
120 MWt	$\simeq$ 20 mmgpd
500 MWt	20 mmgpd
	35 mmgpd
	50 mmgpd

B. Computer Optimization

Since it was necessary to proceed with the computer runs simultaneously with the determination of power and steam costs, based on the capital cost of the reactor power plants being considered, sufficient runs were made to bracket the anticipated steam and power costs. Specifically the following sets of data were selected as the basis for the computer optimization studies:

1. Brine heater exit temperatures - 250° F and 350° F
2. Water production capacities - 1, 20 and 54-1/2 mmgpd
3. Steam costs - 20, 70 and 120 ¢/10^6 Btu.
4. Power costs - 3, 6-1/2 and 10 mills/kwhr



* APPROXIMATE DATA

The above conditions led to 54 cases which were run on the computer. Data for each of the 54 cases are given in Tables 1 through 4, pages 6, 7, 47 and 55 of this report. The computer output data was used as the source for plotting sets of curves of both water plant total costs and performance ratios as a function of water production. Using these curves and the power and steam costs that were determined from the reactor and turbine plant designs, it was possible to obtain the optimum water plant capital costs. In the water production cases, the range from 1 to 54-1/2 mmgpd was covered so that optimization could be obtained for both nuclear reactor water desalination combination plants in the 7 to 50 mmgpd range and for fossil-fueled combination plants in the range 1 to 14 mmgpd.

C. Results

The results of the computer runs, plant designs, cost estimates and subsequent calculations are presented in Table 1, 250° F Brine Temperature, and Table 2, 350° F Brine Temperature. For the nuclear costs in Tables 1 and 2 the cost of the steam (or reactor plant) was based on the thermal output of the plant. Therefore, the various water and electric plant sizes had no effect on the steam plant cost, except in the 350° F brine temperature cases, where an increased steam flow caused a decrease in the cost per 1000 pounds of steam.

The unit costs increased as plant size decreased with the greatest increase coming in the plants under 100 MWt.

In fossil-fueled plants the boiler sizes were based on the water plant size and the performance ratio. As the higher fuel cost dictated a higher performance ratio, the boiler sizes decreased with the increased fuel cost, although the water plant output was held constant. This savings is not reflected in the unit cost of the steam but is evident in the steam cost per 1000 gallons of product water.

There is a rather large increase in unit costs as the water production is decreased to 1 mmgpd. This increase is mainly in the operating and maintenance costs per 1000 pounds of steam, which more than double in going from 7-mmgpd to the 1-mmgpd plant.

The steam cost to the water desalination plant and turbine power plant was based on the cost per 1000 pounds for steam generation. This cost and the weight flow of steam to the brine heater led to the steam cost charged to the water plant. This value subtracted from the steam generator costs gave the steam cost to the turbine plant. The unit cost of the steam to the water plant was derived by multiplying the cost per 1000 pounds of steam at the steam generator by a ratio of enthalpy differences. For the noncondensing turbine plants (Cases 4, 5, 6, 10, 11, 12, 13, 14 and fossil-fired plants), this ratio is the enthalpy of the steam to the brine heater minus the enthalpy of the water from the brine heater over the enthalpy of the steam leaving the steam generator minus the enthalpy of the steam entering the condenser. These ratios varied from .85 to .95.

For the condensing turbines (Cases 1, 2, 3, 7, 8, 9), the ratio was determined in the same way and had a value of .80 for Cases 1, 2, 3, and .68 for Cases 7, 8, 9.

The unit cost of electricity was based on the net generation which was equal to the gross generation minus the auxiliary power required for the steam and turbine plant.

The single-purpose nuclear plant (Case 13) was penalized about 5¢/1000 gallons due to higher electric costs when compared with Case 6, a nuclear dual-purpose plant which has the same thermal size and approximate water output. The single-purpose fossil-fueled plant comparable with Case 13 is Case 16 -- 7.0 mmgpd, 40¢/10^6 Btu, and no electric power for sale. Case 16-C shows water unit costs 18.4¢/1000 gallons less than Case 13 with 5¢/1000-gallons savings in steam costs and 10¢/1000-gallons savings in electric costs. However, if Case 16-C is compared with Case 14 -- 350° F brine temperature, 8.6 mmgpd, no electric power generation -- the difference is only 8.9¢/1000 gallons, with most of the savings coming in the water plant capital cost.

The fossil-fueled cases were not directly comparable with most of the nuclear cases as the fossil-fueled plants were all single purpose.

However, where the dual-purpose nuclear reactor water outputs compared with the output in the fossil-fueled cases water costs did not differ greatly. For example, examination of Cases 4 and 5, nuclear, and Case 17, fossil-fueled, shows that all three are in the 65 to 75¢/1000-gallons range.

The data contained in Table 1 and in other tabulations included in this report were used to prepare the series of curves presented in Figures 2 to 10. The 250° F brine temperature was selected for illustration since the results generally show only slight reductions in water costs when the brine temperature is increased from 250° F to 350° F. The savings in steam and power costs are largely offset by increases in water plant capital costs. In the main, cost differences between 250° F and 350° F brine are too slight to be conclusive.

As was anticipated, the unit costs for producing desalinated water in dual-purpose nuclear plants decreased as the reactor power levels were increased from 40 to 500 MWt and fresh water production levels were increased from 7,000,000 to 20,000,000 gallons per day (mmgpd). However, at the 500-MWt reactor power level there is little change in the unit cost of water for a production range from 20 to 50 mmgpd. Figure 2 shows the variation in unit capital costs, in dollars per gallon per day, of the water desalination plant as a function of water production and with the associated reactor power level noted. That unit capital costs rise sharply as water production is decreased is demonstrated in Figure 2. However, what is also shown is that for a given water production, savings can be effected by increasing the reactor power level. For example, at a water production of 20 mmgpd the unit capital costs can be decreased from $0.97 per gallon per day to $0.76 per gallon per day (a savings of 21.6 percent) by increasing the reactor power level from approximately 120 MWt to 500 MWt.

Figures 3 and 4 show steam and electric power cost, respectively, as a function of reactor power level. The normally expected trend of increasing unit costs with decreasing power levels is maintained in

COMBINED
NUCLEAR POWER PLANT
AND
WATER DESALINATION PLANT

CAPITAL COST OF DESALINATION PLANT
VS.
WATER PRODUCTION
(250°F BRINE TEMPERATURE)

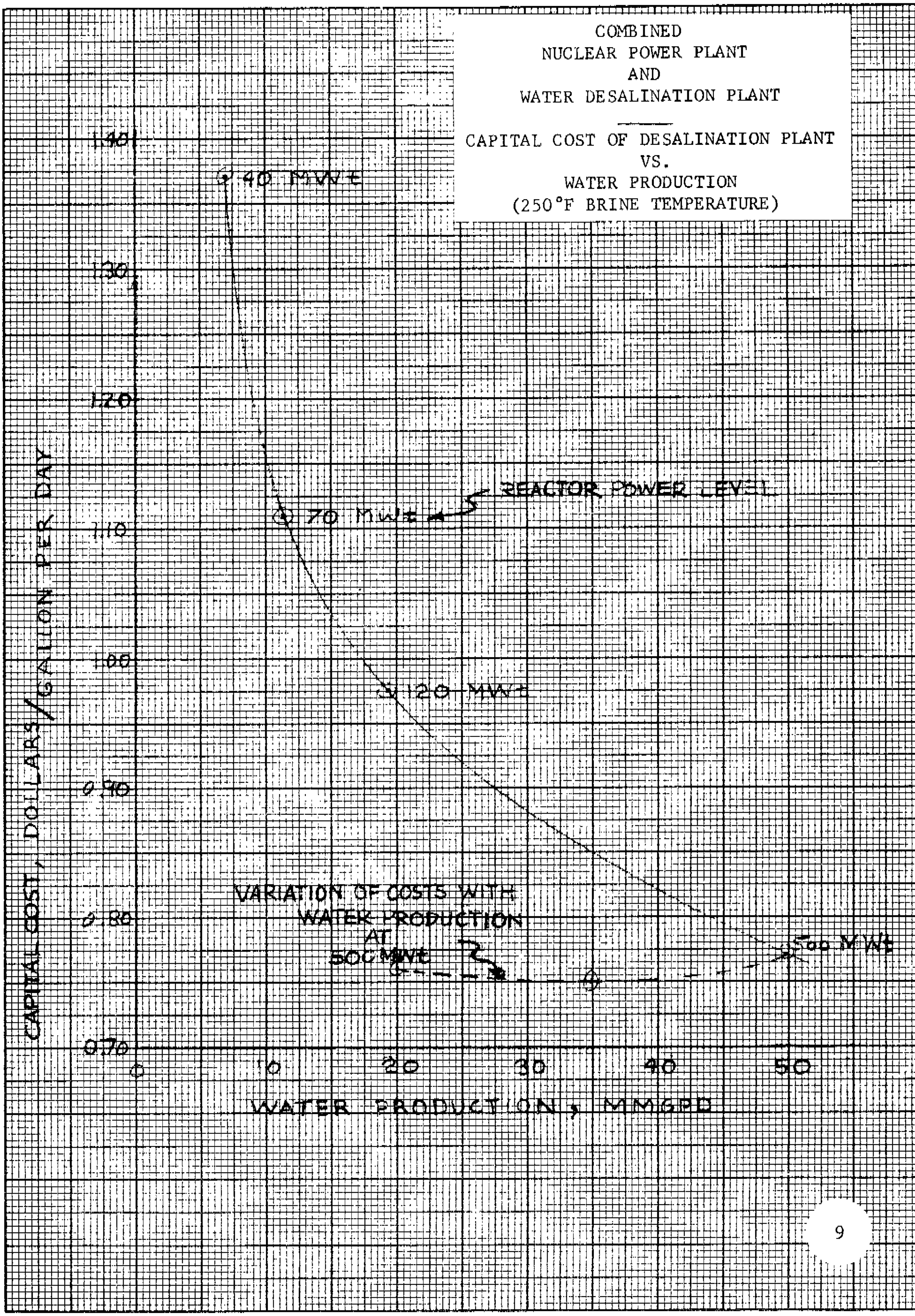
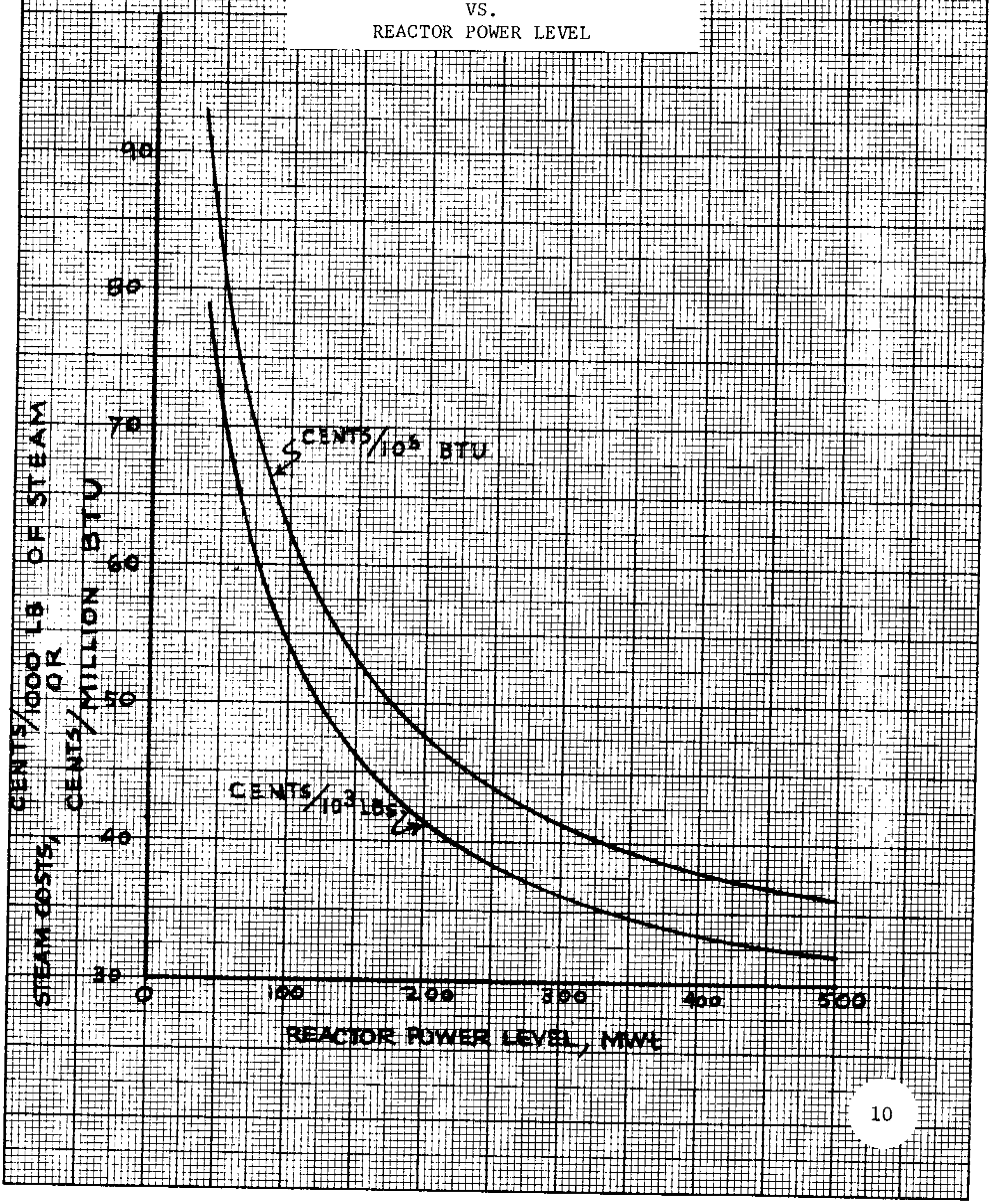


FIGURE 3

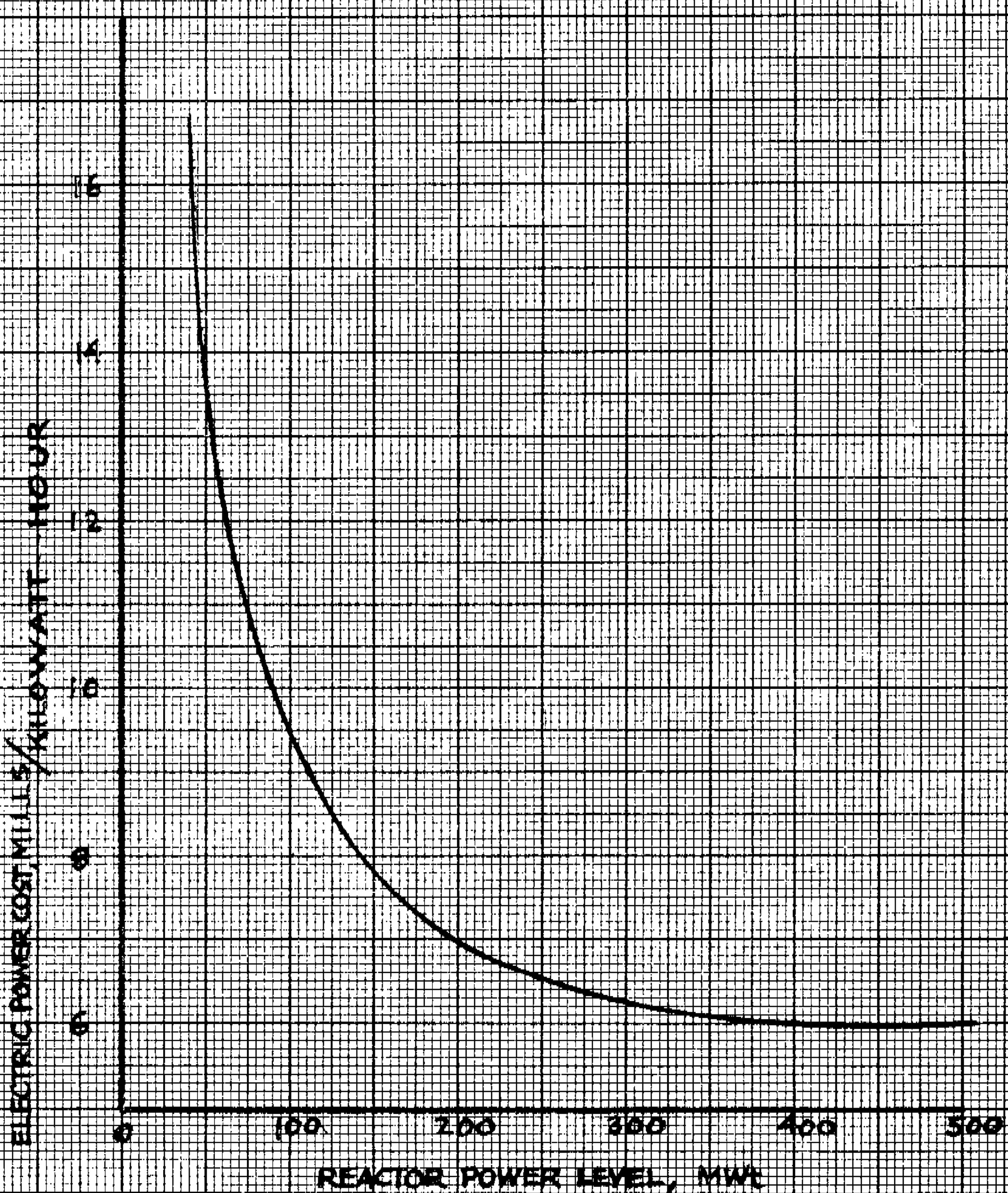
COMBINED
NUCLEAR POWER PLANT
AND
WATER DESALINATION PLANT

STEAM COST
@ STEAM GENERATOR
VS.
REACTOR POWER LEVEL



COMBINED
NUCLEAR POWER PLANT
AND
WATER DESALINATION PLANT

ELECTRIC POWER COST
VS.
REACTOR POWER LEVEL

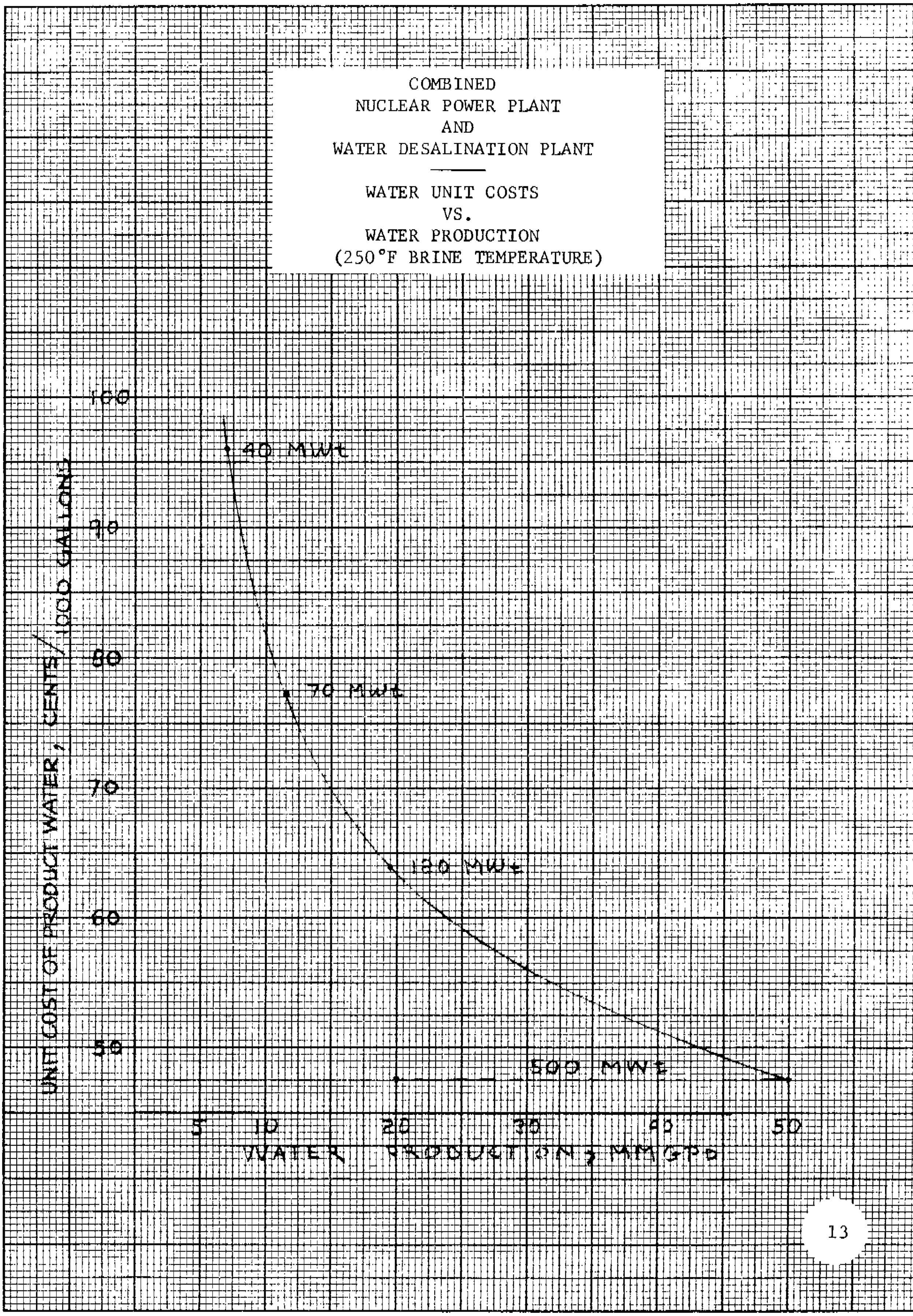


these curves, and the advantages of the larger reactor sizes are readily apparent. Figure 5 presents the unit costs of water as a function of water production. Following the expected trend, the lowest water unit cost occurs at the 500-MWt reactor power level and is fairly constant at about 47 to 48¢/1000 gallons for productions ranging from 20 to 35 mmgpd. The unit costs increased with reduction in production and reactor power level until at the 40-MWt level they more than doubled (96¢/1000 gallons at 40 MWt as compared to 47¢/1000 gallons at 500 MWt).

Much of the data in Table 1 and on Figures 2 to 5 is consolidated and condensed on Figure 6. Figure 6 is designed to permit estimates to be made of steam, capital, and operation and maintenance costs, and total water unit costs, for combinations of reactor power level and water production other than those specifically investigated for this report. The curves on Figure 6 are, of course, only valid for the cost bases used in this report, i.e., a PWR reactor and a flash evaporation water desalination plant using concrete structures to contain the condenser tube bundles. Nevertheless, these curves should prove useful in obtaining quick order-of-magnitude costs.

For the fossil-fueled plants steam, electric power and water unit costs are presented in Figures 7 to 9. No unusual trends are revealed in these figures. As would be expected, water unit costs are increased as fuel costs are raised, the increase in water costs varying from about 10¢/1000 gallons at 1 mmgpd to 20¢/1000 gallons at 14 mmgpd as the fuel (gas) goes from 20¢/million Btu to 40¢/million Btu.

Figure 10 shows the boiler power levels required to achieve water productions up to 20 mmgpd in single-purpose desalination plants. Fuel costs are included as a parameter.


COMBINED
NUCLEAR POWER PLANT
AND
WATER DESALINATION PLANT
WATER UNIT COSTS
VS.
WATER PRODUCTION
(250°F BRINE TEMPERATURE)
40 MWt
70 MWt
120 MWt
500 MWt
UNIT COST OF PRODUCT WATER, CENTS/1000 GALLONS
WATER PRODUCTION, MMGPD

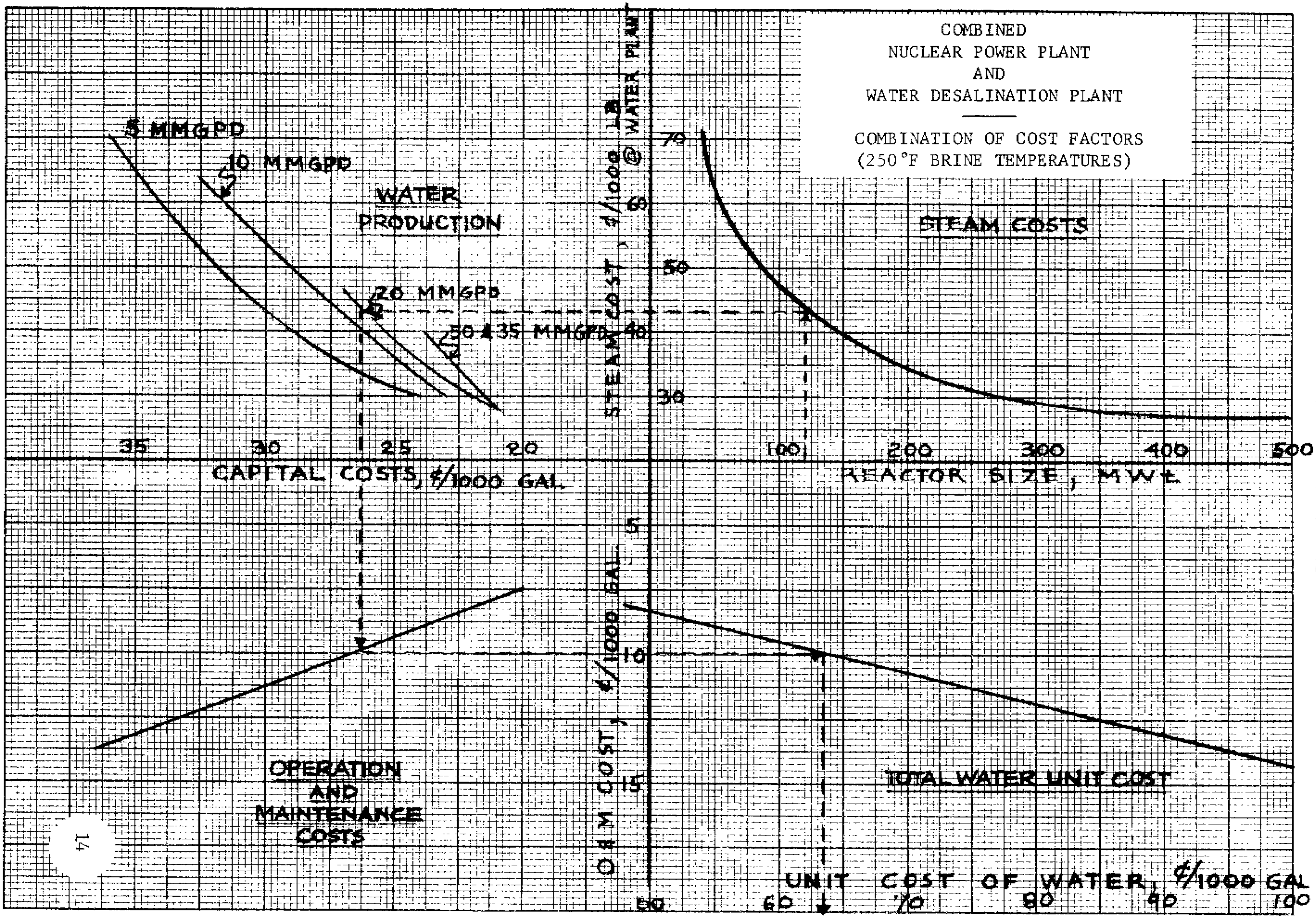
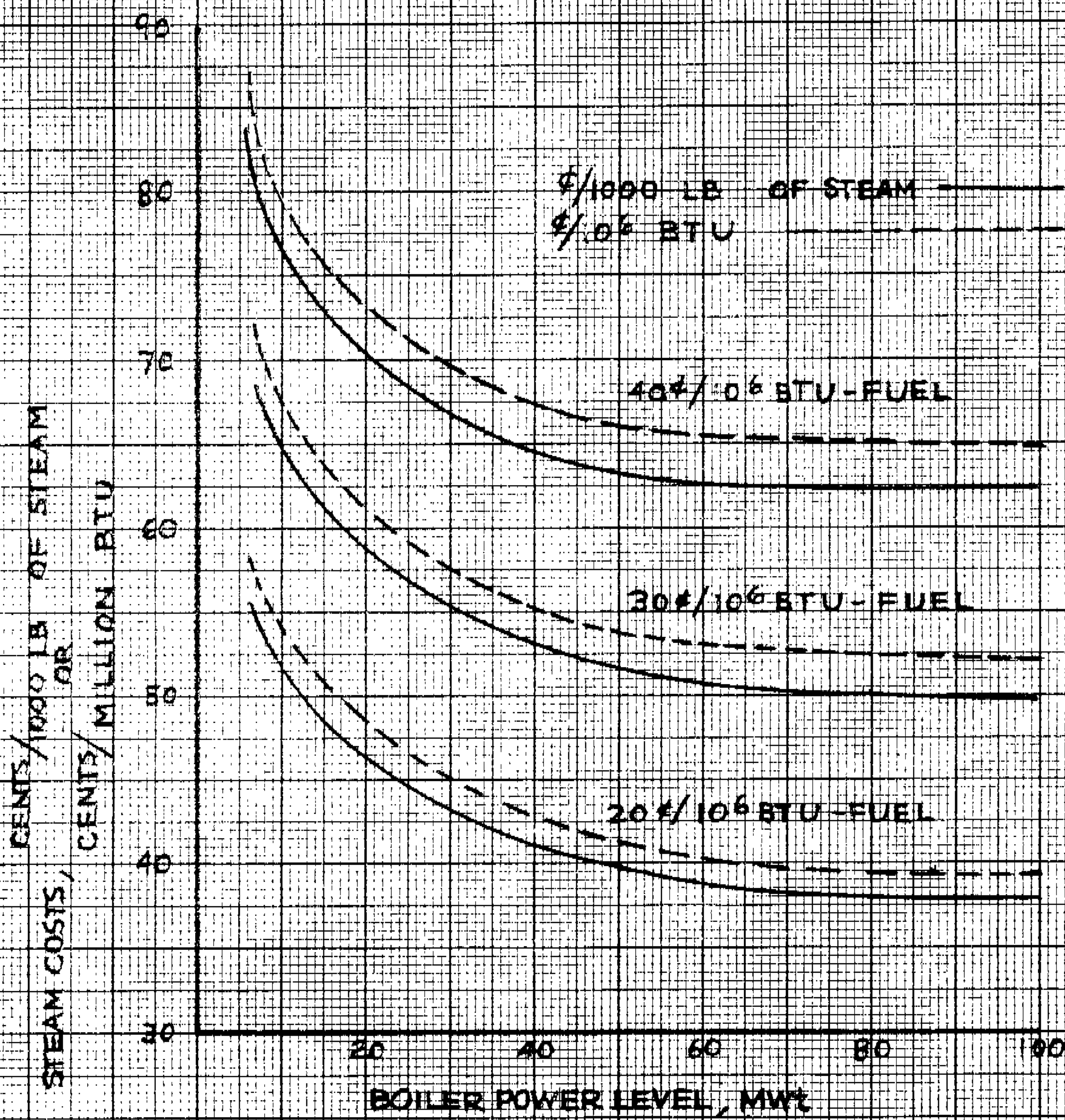
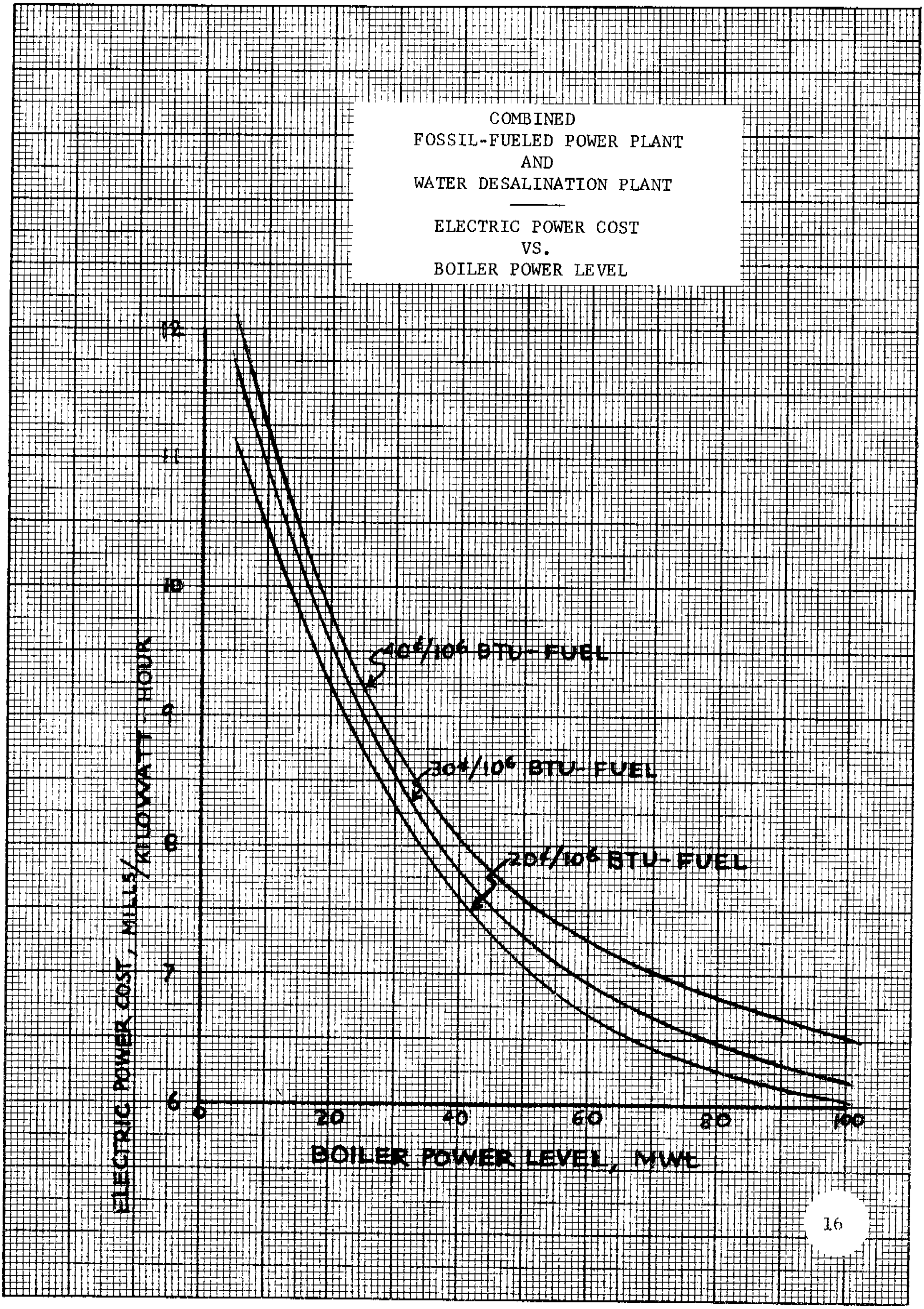

COMBINED
NUCLEAR POWER PLANT
AND
WATER DESALINATION PLANT
COMBINATION OF COST FACTORS
(250°F BRINE TEMPERATURES)
WATER PRODUCTION
5 MMGPD
10 MMGPD
20 MMGPD
30 & 35 MMGPD
STEAM COSTS
STEAM COST, ¢/1000 LB @ WATER PLANT
70
60
50
40
30
35
30
25
20
CAPITAL COSTS, ¢/1000 GAL
100
200
300
400
500
REACTOR SIZE, MWt
O & M COST, ¢/1000 GAL
5
10
15
OPERATION AND MAINTENANCE COSTS
TOTAL WATER UNIT COST
UNIT COST OF WATER, ¢/1000 GAL
50
60
70
80
90
100

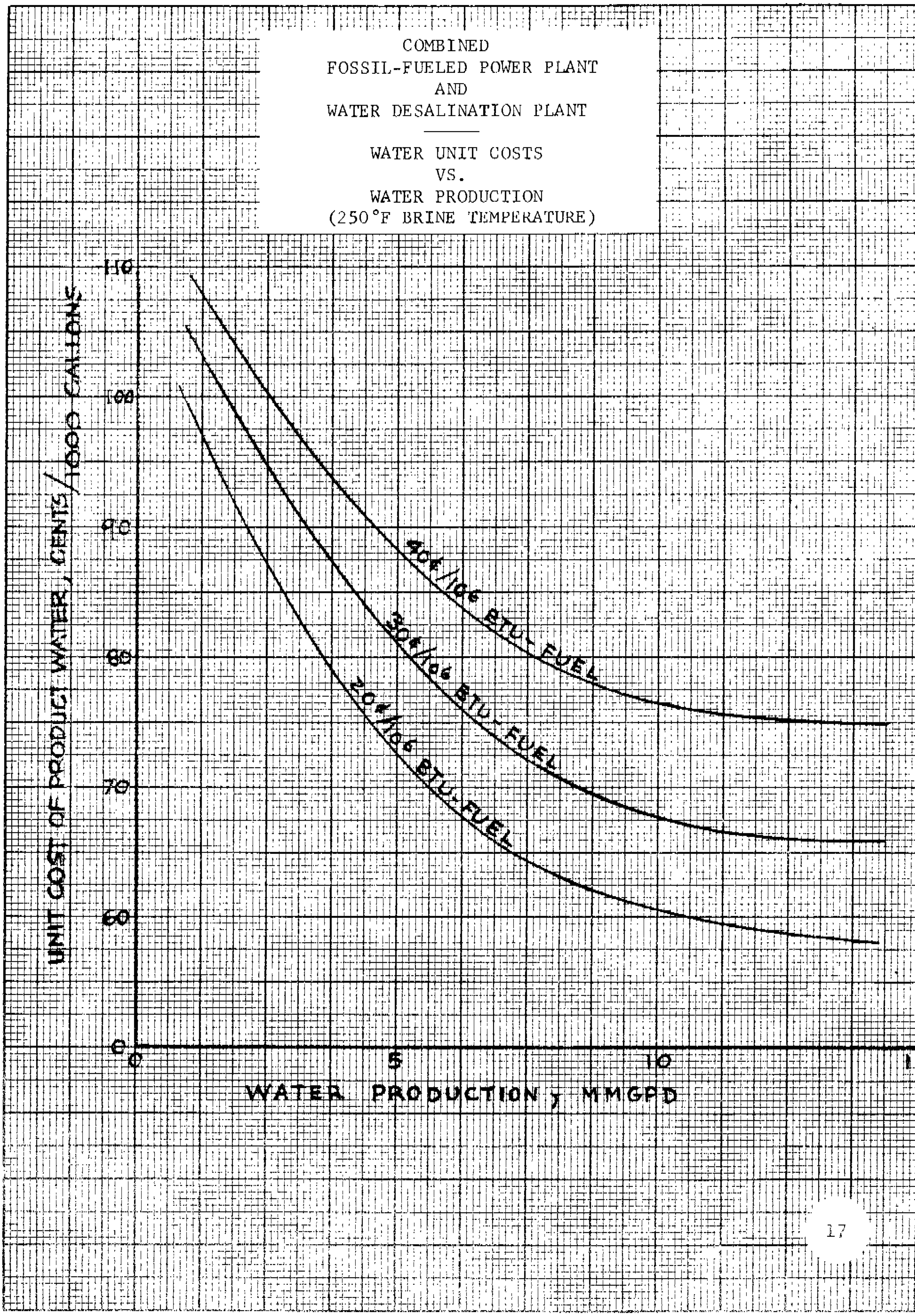
FIGURE 6

COMBINED
FOSSIL-FUELED POWER PLANT
AND
WATER DESALINATION PLANT

STEAM COST
@ STEAM GENERATOR
VS.
BOILER POWER LEVEL

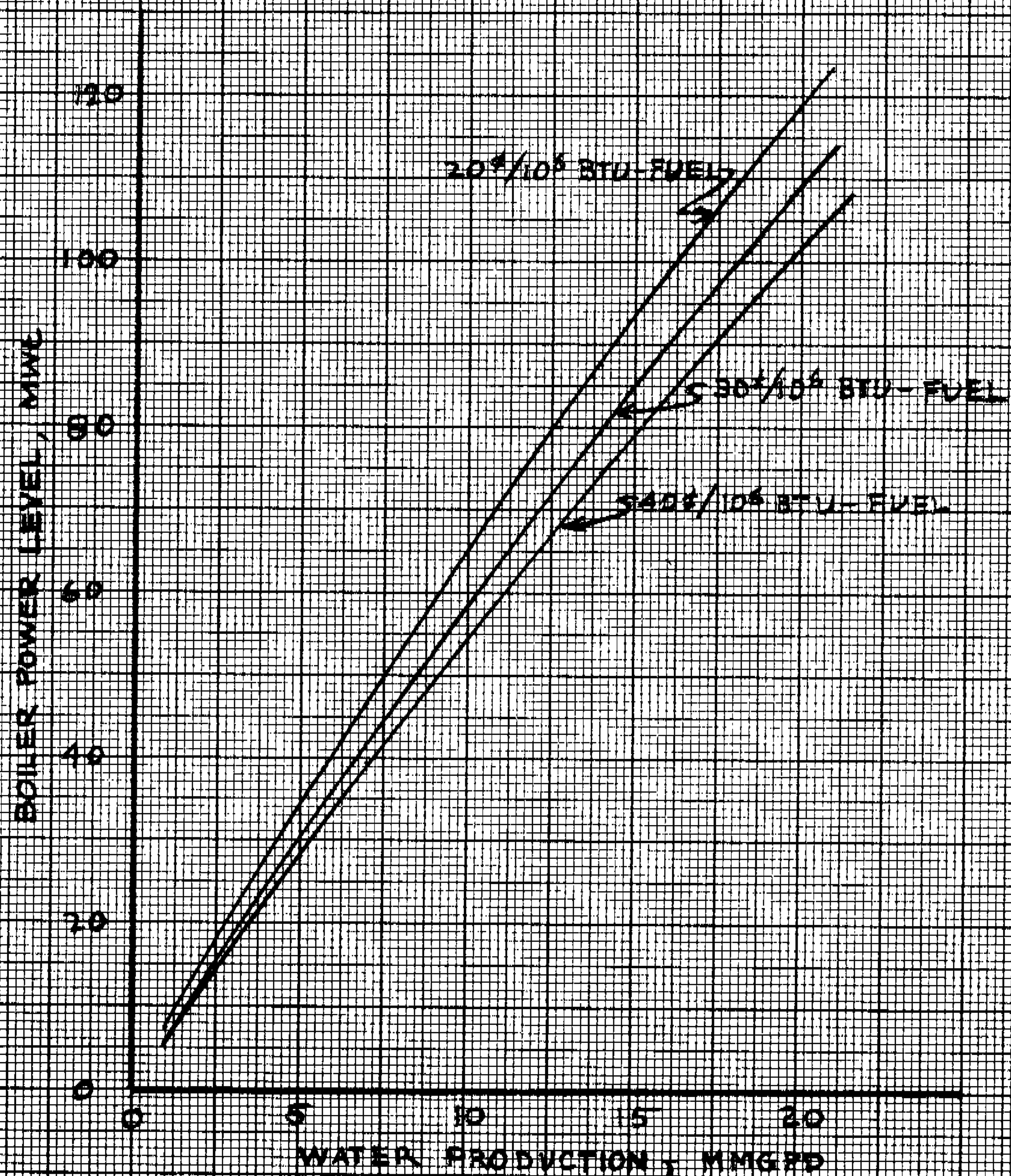



COMBINED
FOSSIL-FUELED POWER PLANT
AND
WATER DESALINATION PLANT
ELECTRIC POWER COST
VS.
BOILER POWER LEVEL
12
11
10
9
8
7
6
0
20
40
60
80
100
40¢/10⁶ BTU-FUEL
30¢/10⁶ BTU-FUEL
20¢/10⁶ BTU-FUEL
ELECTRIC POWER COST, MILLS/KILOWATT-HOUR
BOILER POWER LEVEL, MWt


COMBINED
FOSSIL-FUELED POWER PLANT
AND
WATER DESALINATION PLANT
WATER UNIT COSTS
VS.
WATER PRODUCTION
(250°F BRINE TEMPERATURE)
UNIT COST OF PRODUCT WATER, CENTS/1000 GALLONS
110
100
90
80
70
60
0
40¢/10⁶ BTU-FUEL
30¢/10⁶ BTU-FUEL
20¢/10⁶ BTU-FUEL
0
5
10
15
WATER PRODUCTION, MMGPD

SINGLE-PURPOSE WATER DESALINATION PLANT
FOSSIL-FUELED BOILER

BOILER POWER LEVEL
VS.
WATER PRODUCTION



III. DISCUSSION

A. Selection of Reactor Type and Steam Conditions

In this study only boiling- and pressurized-water reactors were initially considered because of their proven capabilities. The application of a boiling-water reactor as a heat source for water desalination requires an indirect cycle to generate steam for the desalination portion of the plant. This is necessary to prevent potential radioactive contamination of product water by leakage in the brine heater. Since there is insufficient present design background on steam cycle conditions for such a plant (Elk River has fossil-fuel superheat) and time did not permit an optimization for these conditions, the boiling-water reactor was dropped from further consideration. This was not intended to reflect on the capabilities of such a reactor for this type of service; the boiling-water reactor system was ruled out primarily because of the lack of easily available steam cycle data. It is believed that the boiling- and pressurized-water reactors would prove to be competitive in a more extensive study.

A review, summarized on page 20, was made of secondary system conditions of pressurized-water reactors (shown schematically on Figure 11). The data on the SELNI plant was added after selection of system conditions. Although this plant is located in Europe, it was designed by a United States firm and is nearly completed, with criticality due in February, 1964. In selecting steam conditions it was felt that data indicative of present practice with operating pressurized-water reactors would be more meaningful. This eliminated consideration of the higher values projected for Consolidated Edison's proposed Ravenswood nuclear power plant in Queens, New York City. The 500-psia steam pressure selected falls within the spread shown in Table 1 and is close to the pressure for Yankee, the most efficient plant listed. As with all the cases tabulated, the steam is saturated (467° F). Since the steam pressure

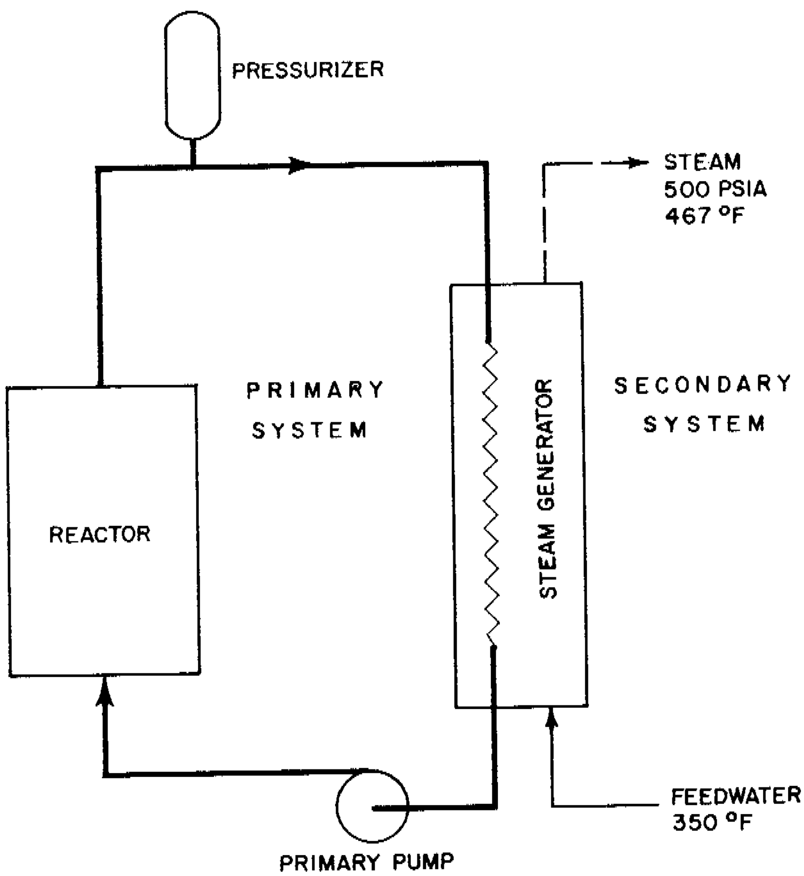
SECONDARY SYSTEM CONDITIONS
PRESSURIZED-WATER REACTORS

PLANT	Reactor Power Level, MWt	Steam Pressure, psia	Steam Temperature °F	Feed-water Temperature °F	Steam Flow lb/hr
Saxton	20	600	486	250	6.9×10^4
Shippingport - Core I	231	600	486	315	8.6×10^5
Yankee	485	467	460	335	1.84×10^6
Shippingport - Core II	505	600	486	338	1.94×10^6
Indian Point	585	420	449	332	2.2×10^6
SELNI	825	500	467	338	3.15×10^6
Ravenswood	2030	700	503	435	8.8×10^6

All data except Ravenswood from IAEA "Directory of Nuclear Reactors," Vol. IV. Ravenswood data from "Atomics," February, 1963. For plants with separately fired superheaters the power levels and steam conditions are those attainable without the superheaters.

PARAMETRIC COST STUDIES

PRESSURIZED-WATER REACTOR
TYPICAL FLOW DIAGRAM - PRIMARY SYSTEM



and temperature chosen are slightly higher than for Yankee, the temperature of the feedwater to the steam generators was adjusted accordingly to 350° F, this again being slightly higher than that used at the Yankee power reactor. The conditions obtained from this reasoning appear to be verified by those listed for SELNI which is the most recent plant beyond proposal stage.

B. Nuclear Island Capital Costs

The nuclear island, as referred to in this report, consists of all facilities associated with steam generation. It includes equipment items such as the reactor, the primary system and auxiliary nuclear systems as well as architect-engineer items such as the containment vessel, spent fuel building and reactor auxiliary building. Data used as a basis for these costs are plotted in Figure A-1. This figure shows nuclear island and total plant curves for power stations as a function of reactor thermal rating. Although the curves on total plant costs are not applicable to this study, they provide a basis for judging the reliability of the nuclear island costs. As indicated by the legend, the nuclear island capital costs were obtained from, or based on, data supplied by reactor manufacturers. They include all cost items which the purchaser would pay to the reactor vendor for the complete package. This includes indirect costs, such as engineering, which are paid by the vendor. Not included is interest during construction, the common facilities costs allocated to the nuclear island, or land costs which are accounted for in the determination of unit costs.

The total plant cost curves based on TID-8533 and the AEC Report to the President are useful for indicating trends and relative values. They are not likely to be as reliable as the total plant costs furnished by General Electric which are based on current firm price quotations. This curve in turn provided a basis for evaluating the nuclear island capital cost curves. Since it is unlikely that the nuclear island capital cost could exceed the total plant cost, the curve based on the Allis-Chalmers data was selected as the most valid. This is shown on Figure 12.

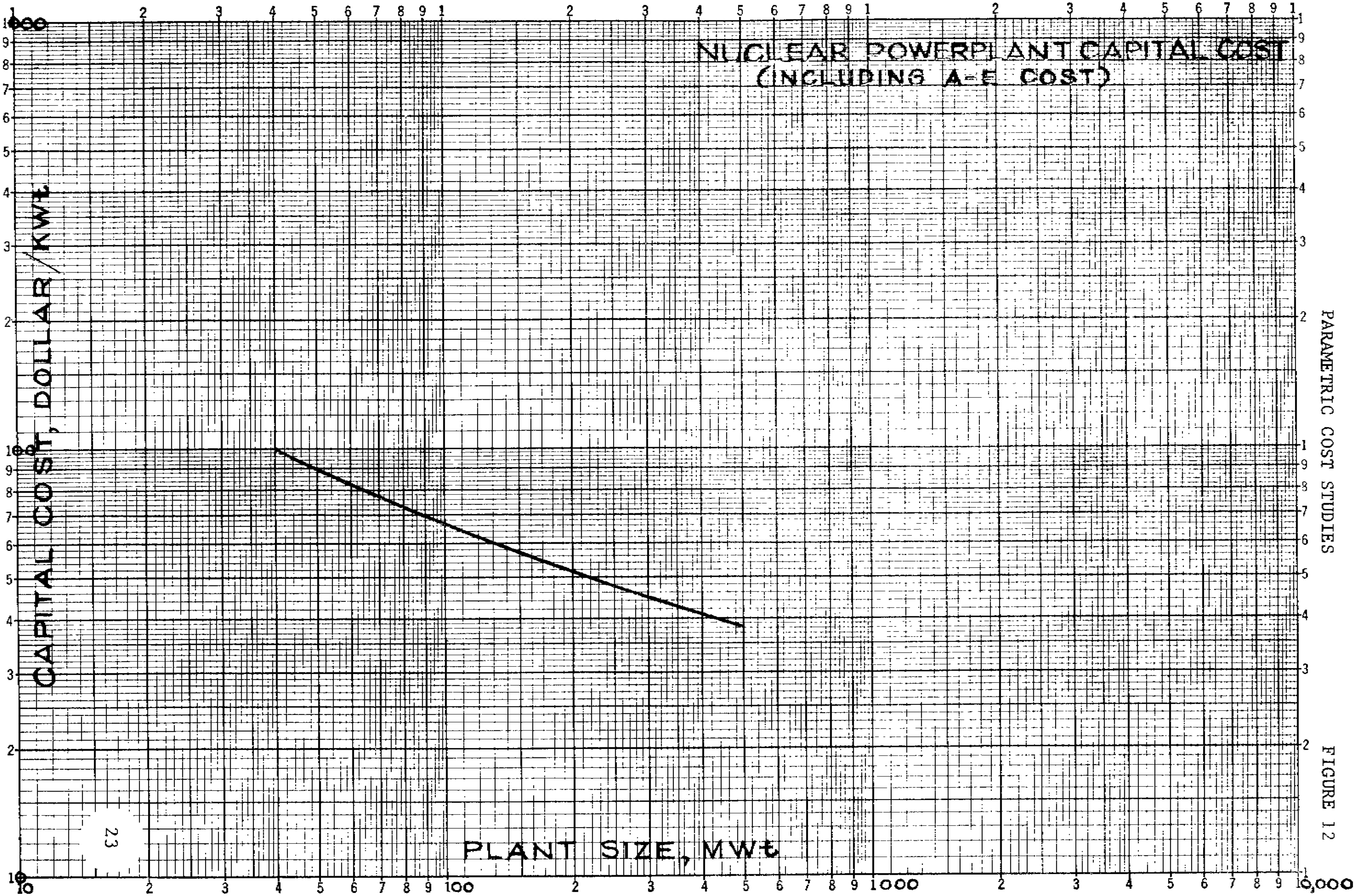

NUCLEAR POWERPLANT CAPITAL COST
(INCLUDING A-E COST)
CAPITAL COST, DOLLAR/KWt
PLANT SIZE, MWt
10
100
1000
10,000

FIGURE 12

It should be noted that, although the costs are based on a boiling-water reactor design, it is felt they apply equally to pressurized-water designs, because of the present highly competitive costs for the two designs.

Capital costs for the nuclear steam generation plants of Cases 13 and 14 were not obtained from the curve on Figure 12. A PWR-type nuclear process steam plant such as would be provided for a single-purpose (no electricity for sale) desalination plant would be designed to operate at lower pressures than a comparable plant for electricity generation. Therefore, the capital investment required for the Cases 13 and 14 single-purpose nuclear plants was estimated on the assumption that the design would be similar to the PWR plant described in ANL-6009 "Study of 40 MW Pressurized Water, Boiling Water and Organic Moderated Reactors for Production of Process Steam."

C. Fuel Costs

Fuel costs used as a basis for determining the cost relation for this study are plotted in Figure A-2. The General Electric costs were considered the most reliable, because they are based on current fixed price bids. A curve drawn through these points to obtain an extrapolation at lower power levels must follow the same trend as the other curves. This requirement was met by drawing the final curve to include the data supplied by Allis-Chalmers. The resulting curve, which appears as a solid line, is repeated as Figure 13.

D. Operation, Maintenance and Insurance Costs

Operation and maintenance costs were determined from data in Section 530 of TID-7025, "Nuclear Power Plants Cost Evaluation Handbook." Figure 530-2 in this handbook shows a curve of total labor and fringe benefits, maintenance materials and operating supplies for all plants as a function of plant electrical rating. Using an efficiency of 30 percent this curve was replotted as a function of plant thermal rating to obtain the curve in Figure 14 for total annual operating and maintenance costs. Since the largest part of these costs results from labor and fringe benefits, the division of costs between the reactor and turbine

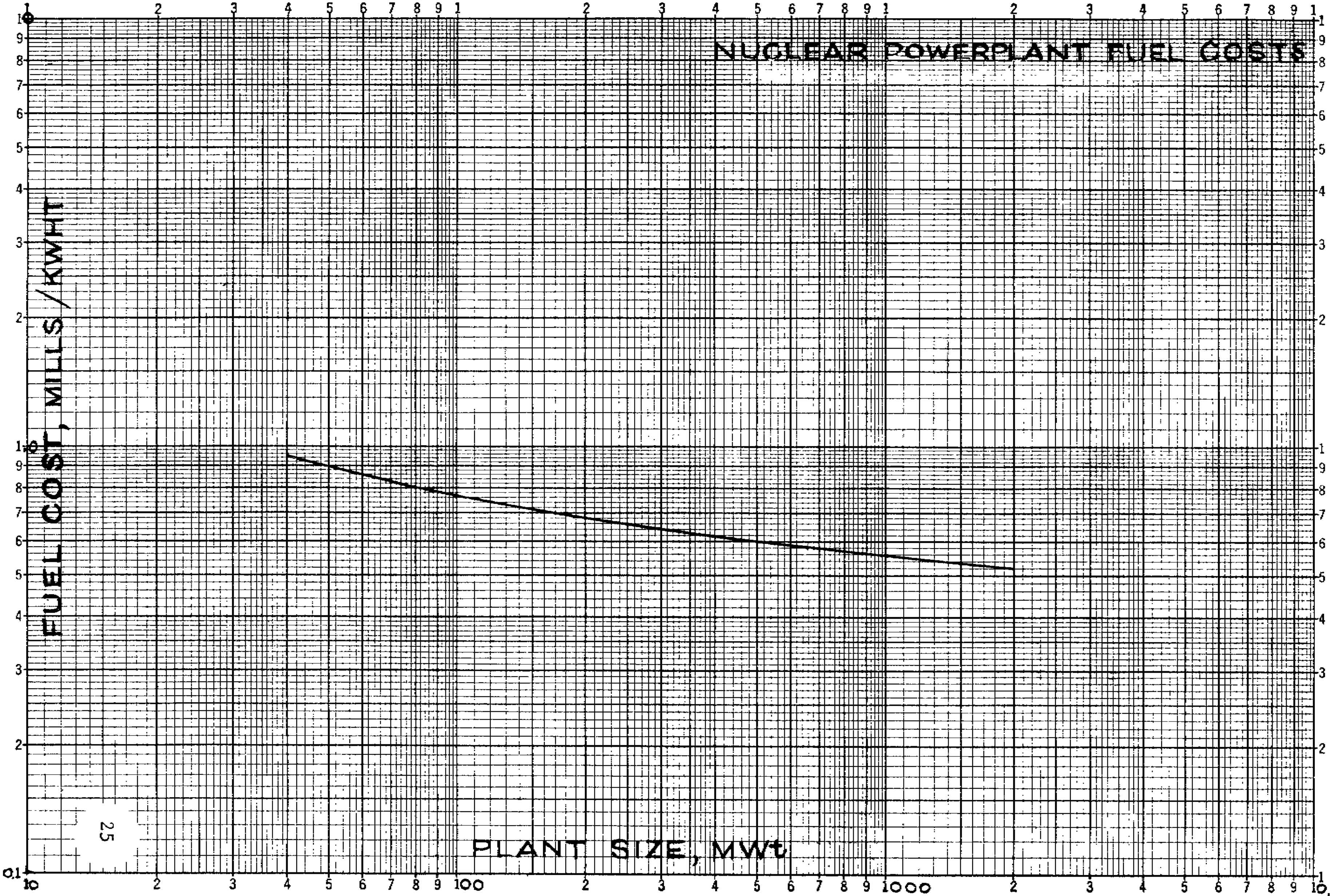
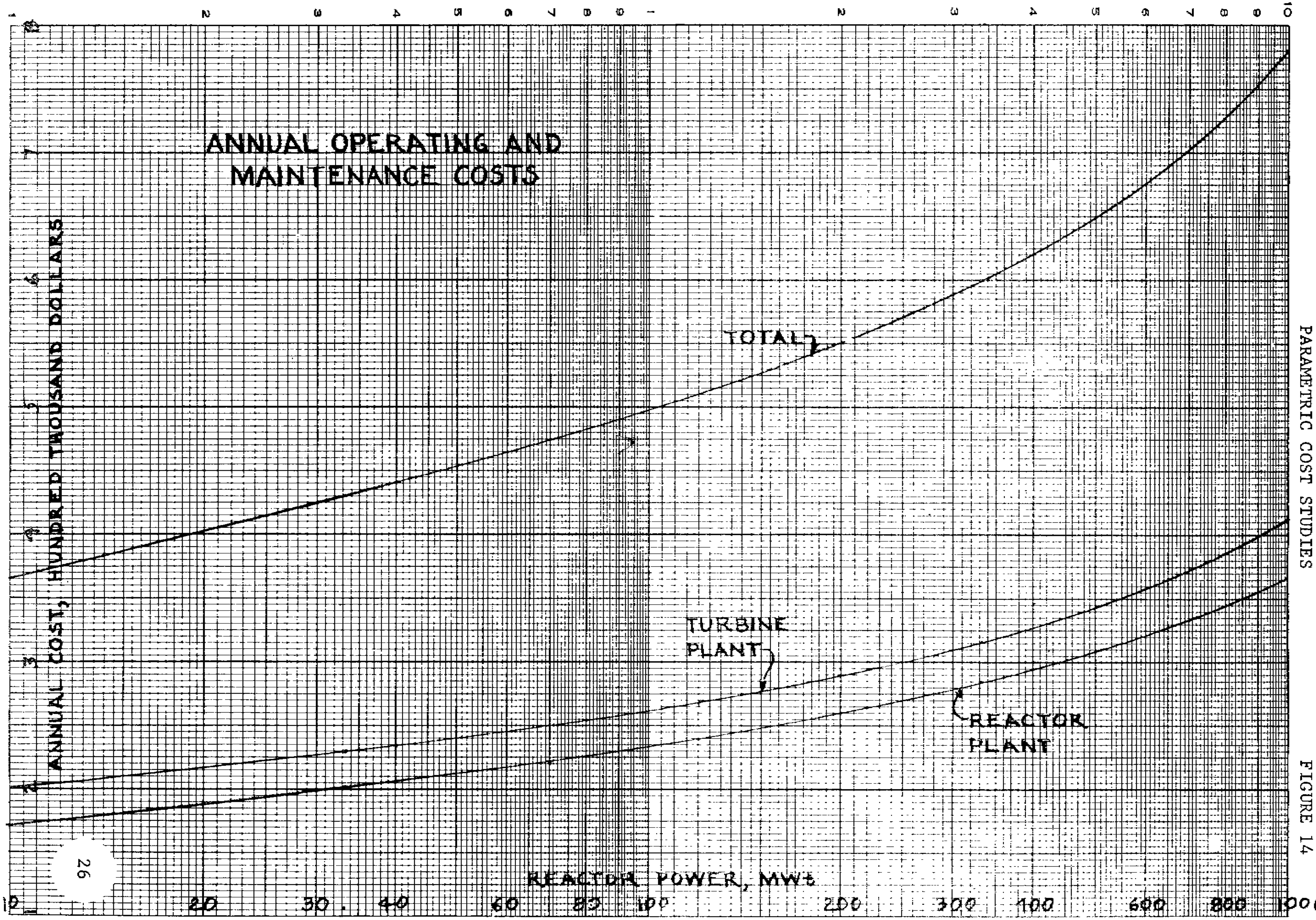

NUCLEAR POWERPLANT FUEL COSTS
FUEL COST, MILLS / KWHT
PLANT SIZE, MWt
10
100
1000
10,000
0.1
1.0
10

FIGURE 13



PARAMETRIC COST STUDIES

FIGURE 14

plant was prorated on the basis of the labor charged to each. The labor and fringe-benefit costs were calculated from personnel requirements and salaries given in TID-7025. Operating costs for personnel such as nuclear engineers were charged to the reactor plant, while costs for personnel such as turbine operators were charged to the turbine plant. Labor costs attributable to personnel likely to work in either plant were divided equally between the reactor and the turbine plant.

Subtraction of the labor and fringe-benefit costs from the total operating and maintenance costs resulted in the curve for total cost of maintenance materials and operating supplies shown in Figure 15. The distribution of this cost between turbine and reactor plant was made on the same basis as for the case of the operating and maintenance costs already discussed.

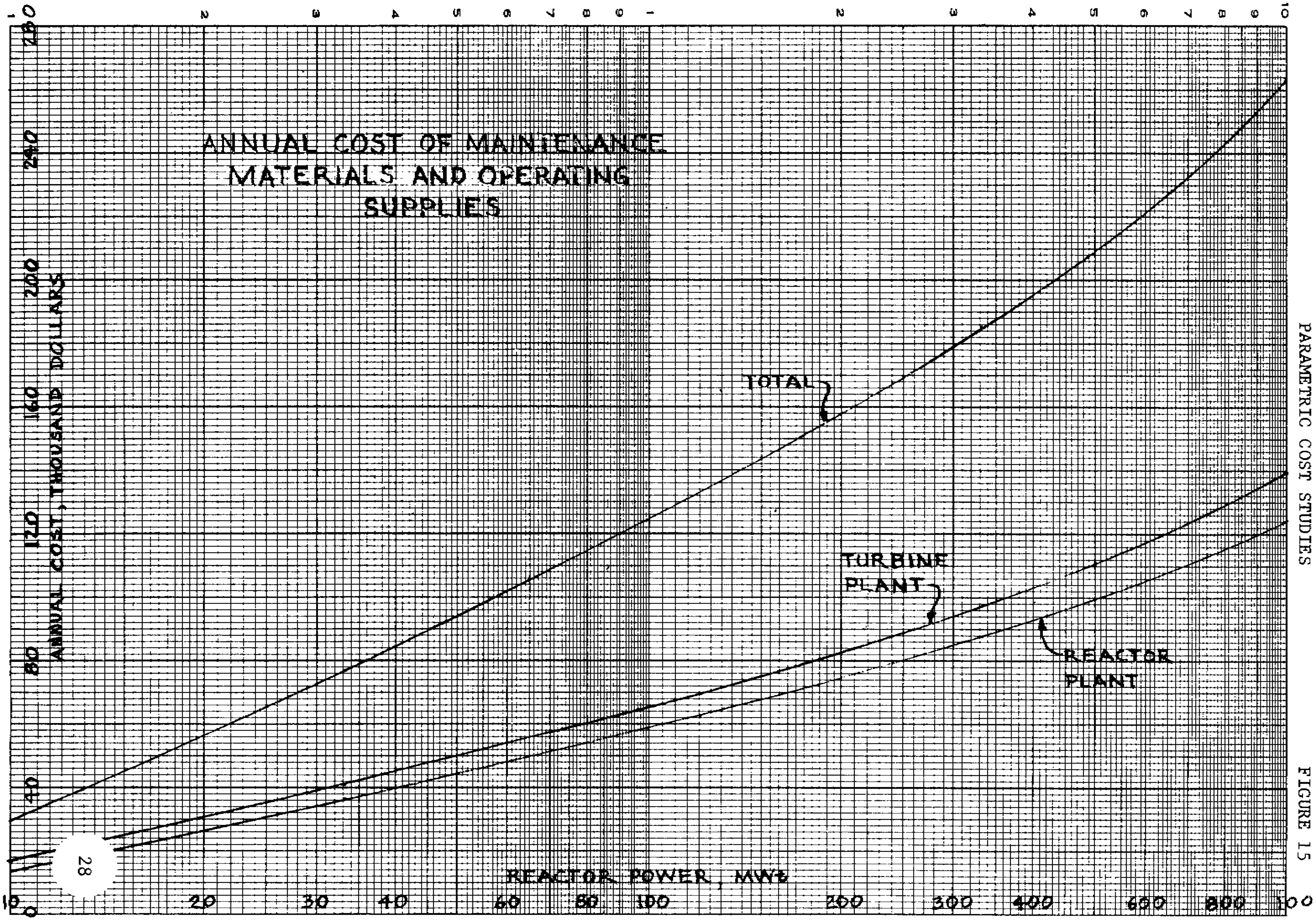
Operation and maintenance costs for the fossil-fueled plants are shown on Figure 16.

The required financial protection for liability was calculated on the basis of 10 CFR 140 for population factors of 1.0 and 2.0. These requirements are plotted in Figure 17. The application of 10 CFR 140 leads to an inconsistency evidently due to the fact that dual-purpose reactors, such as those considered here, were not contemplated. However, it is felt that the intention was for the curves to be based on a 25 percent cycle efficiency. Applying the graduated premium scale on Figure 18 to the curves for the required financial protection gave the curves in this figure for the private premium. The premium paid to the government was added to this to obtain the curves for the total premium. In the evaluation of unit costs, a population factor of 1.0 was used because this is the basis suggested by the cost evaluation ground rules in Section 110 of TID-7025.

E. Turbine Plant

1. Choice of Cycles and Heat Balances

For all cases, cycle selection and heat balance calculations were based on simultaneous operation of both the desalination and



ANNUAL COST OF MAINTENANCE MATERIALS AND OPERATING SUPPLIES
ANNUAL COST, THOUSAND DOLLARS
REACTOR POWER, MWt
TOTAL
TURBINE PLANT
REACTOR PLANT
0
40
80
120
160
200
240
280
10
20
30
40
60
80
100
200
300
400
600
800
1000

FIGURE 15

PARAMETRIC COST STUDIES

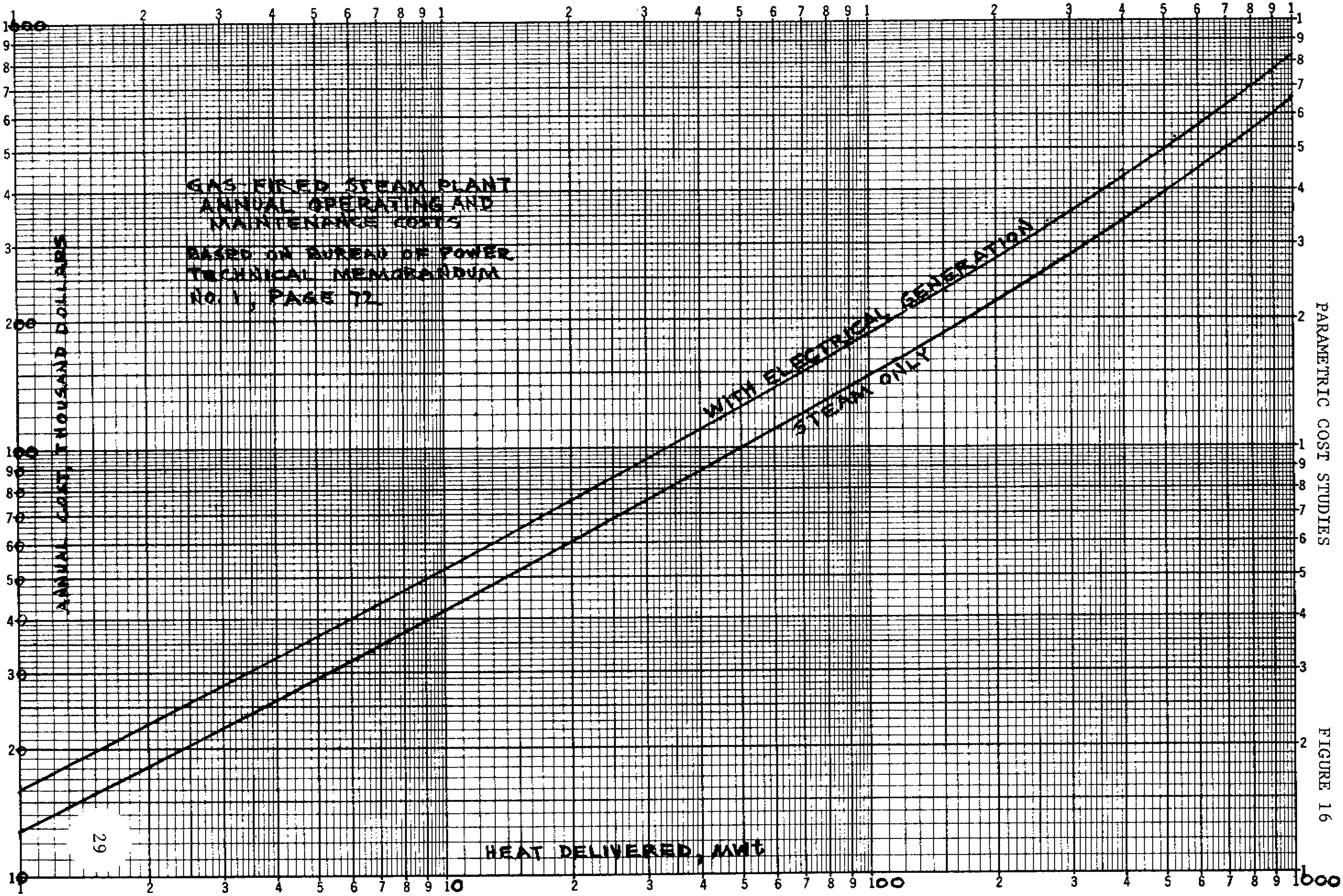
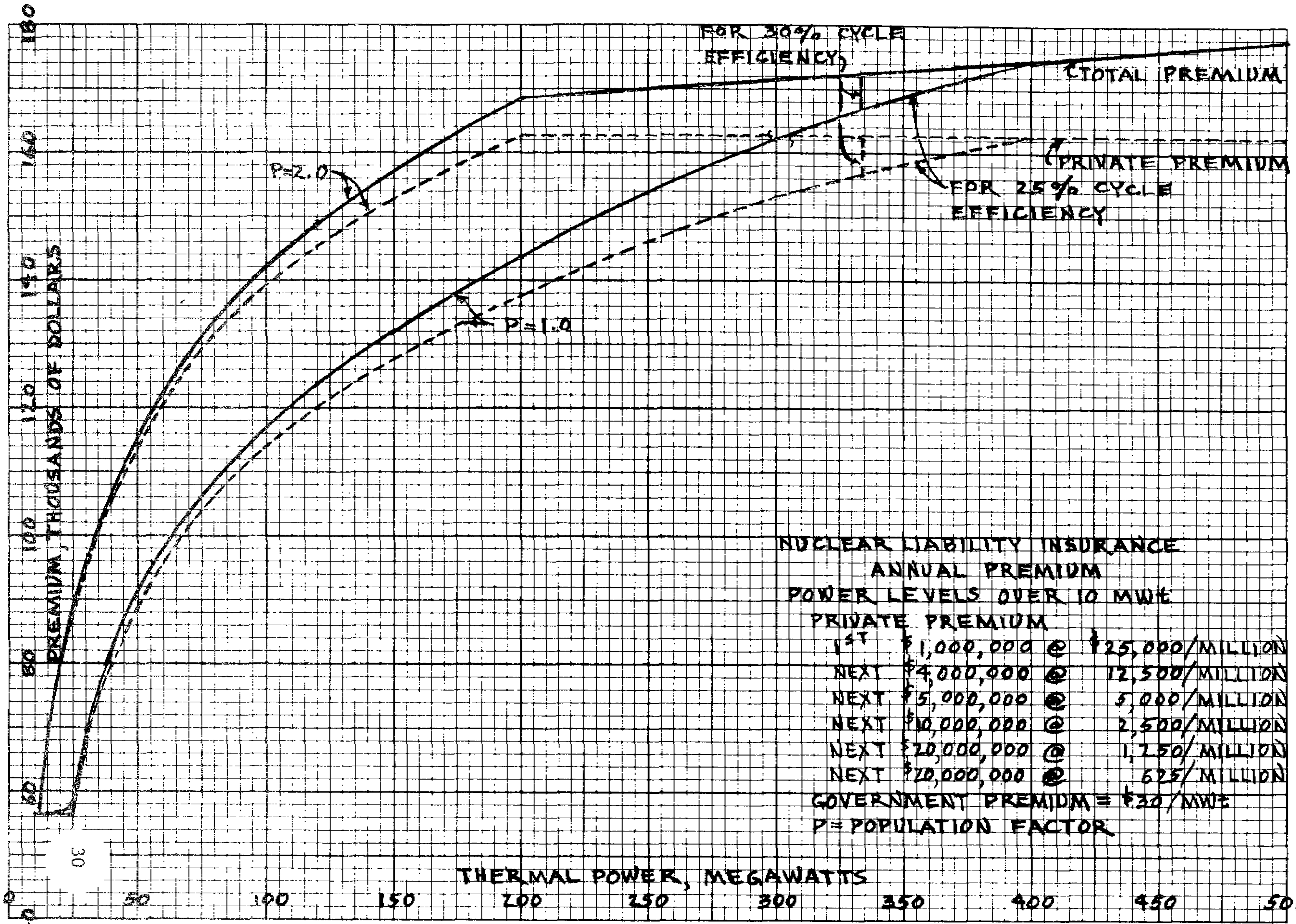
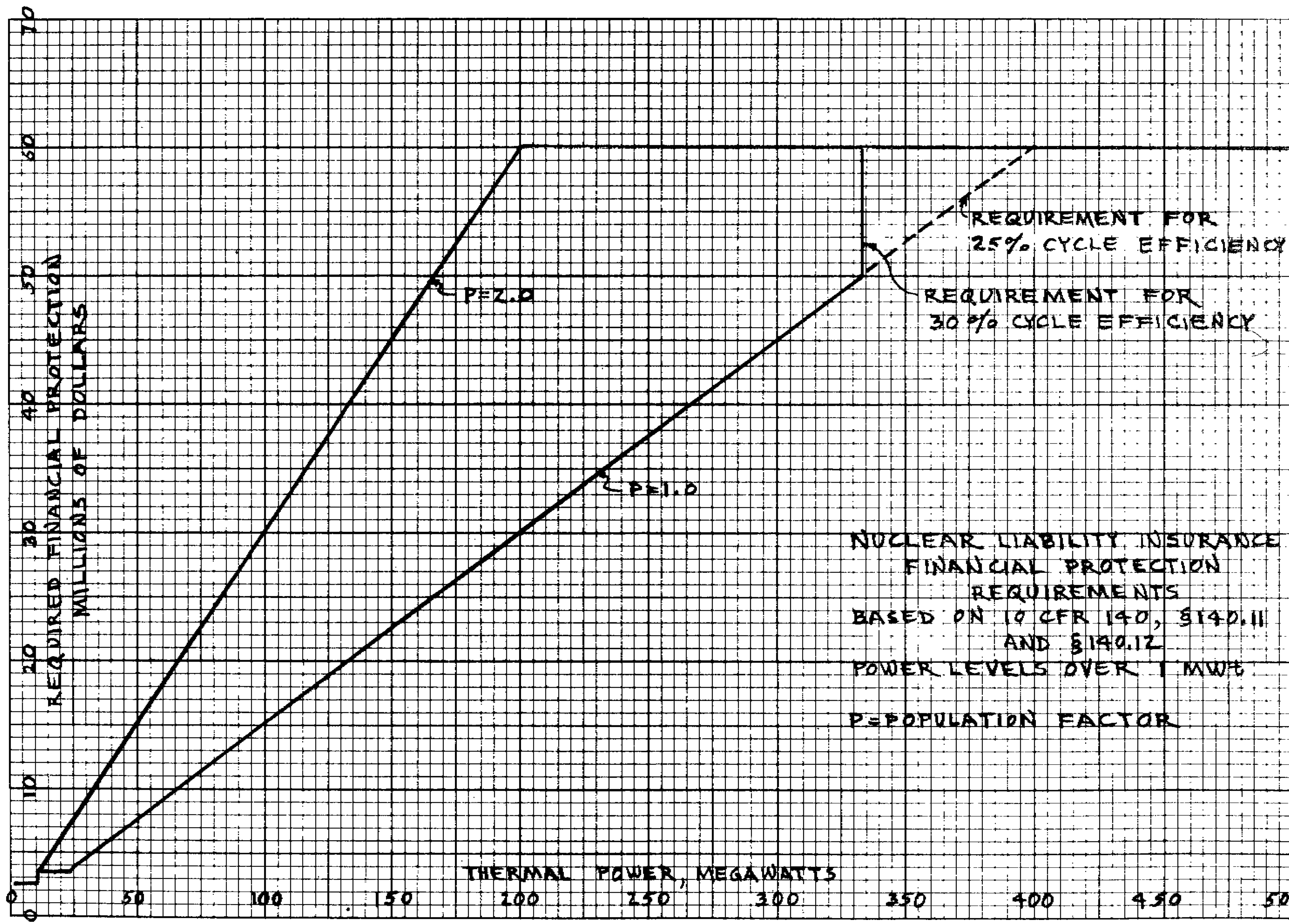


FIGURE 16



FOR 30% CYCLE EFFICIENCY
TOTAL PREMIUM
PRIVATE PREMIUM
FOR 25% CYCLE EFFICIENCY
P=2.0
P=1.0
PREMIUM, THOUSANDS OF DOLLARS
THERMAL POWER, MEGAWATTS
NUCLEAR LIABILITY INSURANCE
ANNUAL PREMIUM
POWER LEVELS OVER 10 MWt
PRIVATE PREMIUM
1ST \$1,000,000 @ \$25,000/MILLION
NEXT \$4,000,000 @ 12,500/MILLION
NEXT \$5,000,000 @ 5,000/MILLION
NEXT \$10,000,000 @ 2,500/MILLION
NEXT \$20,000,000 @ 1,250/MILLION
NEXT \$20,000,000 @ 625/MILLION
GOVERNMENT PREMIUM = \$30/MWt
P = POPULATION FACTOR

FIGURE 17



REQUIRED FINANCIAL PROTECTION MILLIONS OF DOLLARS
THERMAL POWER, MEGAWATTS
0
10
20
30
40
50
60
70
50
100
150
200
250
300
350
400
450
500
P=2.0
P=1.0
REQUIREMENT FOR 25% CYCLE EFFICIENCY
REQUIREMENT FOR 30% CYCLE EFFICIENCY
NUCLEAR LIABILITY INSURANCE FINANCIAL PROTECTION REQUIREMENTS
BASED ON 10 CFR 140, §140.11 AND §140.12
POWER LEVELS OVER 1 MWt
P=POPULATION FACTOR

FIGURE 18

electric generating plants at design conditions. Separate operation of turbine generators at design conditions with partial or zero water production and simultaneous operation of both plants at partial loads were not considered. Auxiliary power requirements are shown on Figure 19.

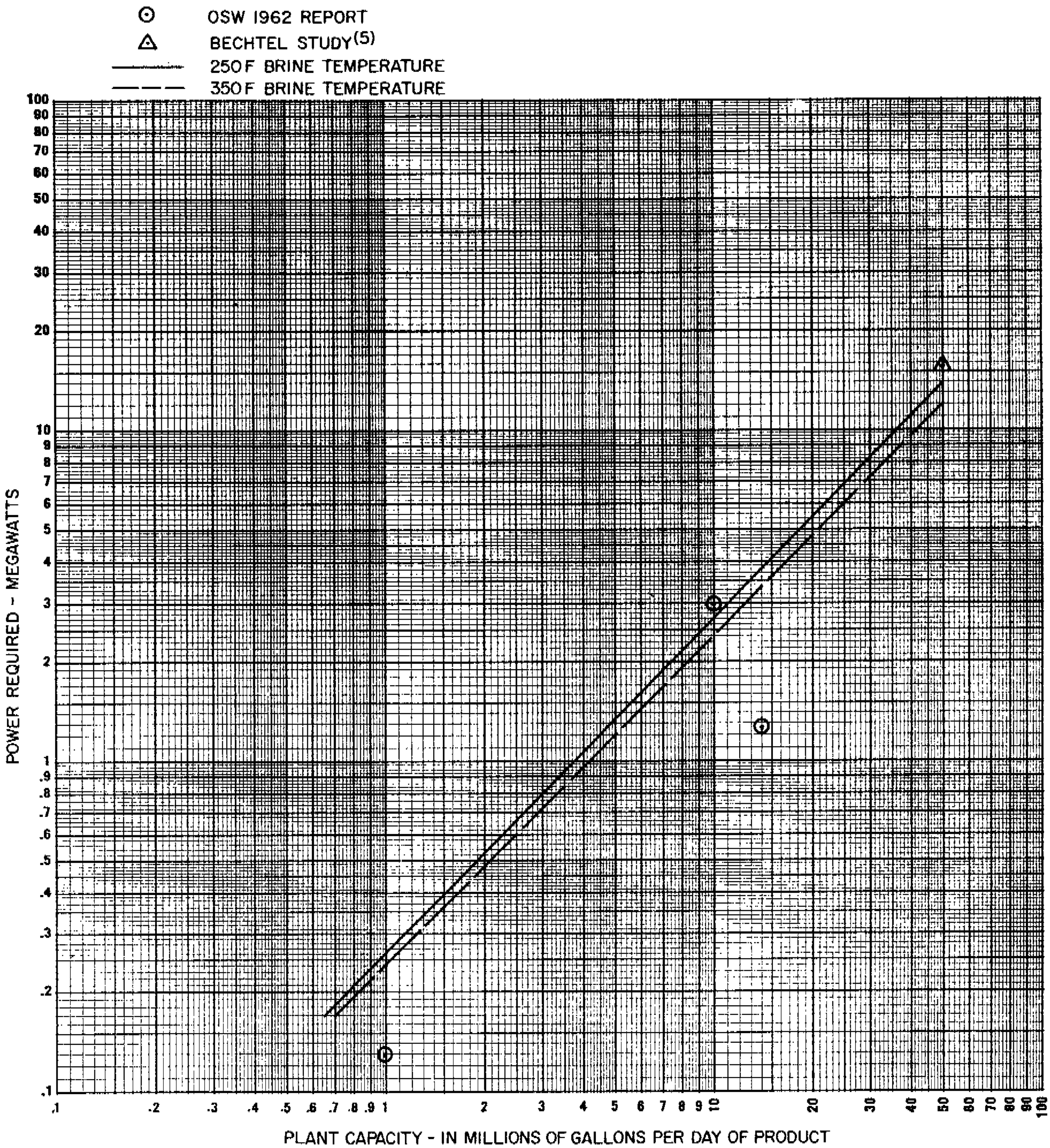
Although heat balances presented herein were based on the best available data, they are intended for study and cost estimating purposes only. The procedures used and the results of this study were based on determining the relative differentials between the various alternative cases. Additional detail investigation would be required for final design performance and data.

a. Nuclear Plants

Based on reactor thermal ratings, steam conditions and feedwater temperatures discussed in Subsection A, preceding, turbine cycles were selected to efficiently utilize all steam which was not required by the desalination plant. The resultant cycles for nuclear dual-purpose plants are shown on individual heat balances for Cases 1 through 12 (Figures 20 to 31).

Heat balances have not been included for the single-purpose nuclear plants, Cases 13 and 14, due to their simplicity and similarity to many other heat balances which are included. In accordance with study criteria, both cases utilized reactors rated at 40 MWt. Case 13 was based on electric generation sufficient to provide total demands for both the desalination and turbine generator plants, whereas Case 14 was based on no electric generation and the reactor supplied steam to the desalination plant only. This resulted from the unique selection of the reactor complex for these cases which limited the steam from the complex to a maximum of 195.8 psia saturated. Hence, for Case 14 with 160-psia steam required at the brine heater, utilization of a noncondensing turbine was not feasible and use of a condensing turbine was not considered justified due to the limited electric generation required. The cycle arrangement for Cases 13 and 14 is similar to the single-purpose fossil-fuel cases, except Case 14 did not include

POWER REQUIREMENTS FOR WATER DESALINATION PLANTS



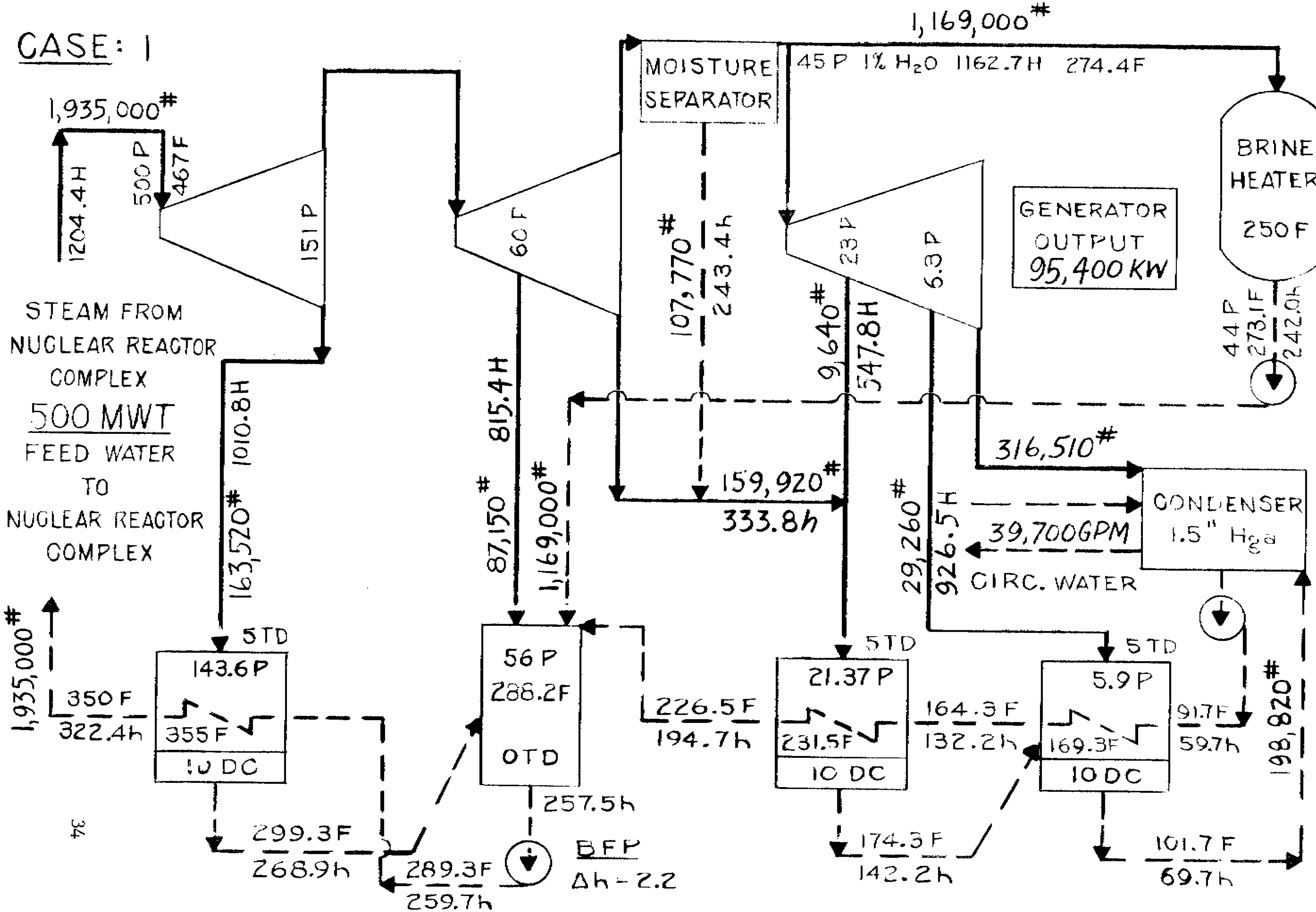

CASE: 1
1,935,000#
500 P
467 F
1204.4 H
151 P
STEAM FROM
NUCLEAR REACTOR
COMPLEX
500 MWT
FEED WATER
TO
NUCLEAR REACTOR
COMPLEX
1010.8H
163,520#
60 F
815.4H
87,150#
1,169,000#
MOISTURE
SEPARATOR
107,770#
243.4h
1,169,000#
45 P 1% H_2O 1162.7H 274.4F
23 P
6.3 P
9,640#
547.8H
GENERATOR
OUTPUT
95,400 KW
BRINE
HEATER
250 F
44 P
273.1F
242.0h
316,510#
159,920#
333.8h
29,260#
926.5H
39,700GPM
CIRC. WATER
CONDENSER
1.5" Hga
5TD
143.6P
355 F
10 DC
350 F
322.4h
1,935,000#
299.3F
268.9h
289.3F
259.7h
56 P
288.2F
OTD
257.5h
BFP
Δh - 2.2
226.5 F
194.7h
5TD
21.37 P
231.5F
10 DC
174.3 F
142.2h
164.3 F
132.2h
5TD
5.9 P
169.3F
10 DC
91.7F
59.7h
101.7 F
69.7h
198,820#

FIGURE 20

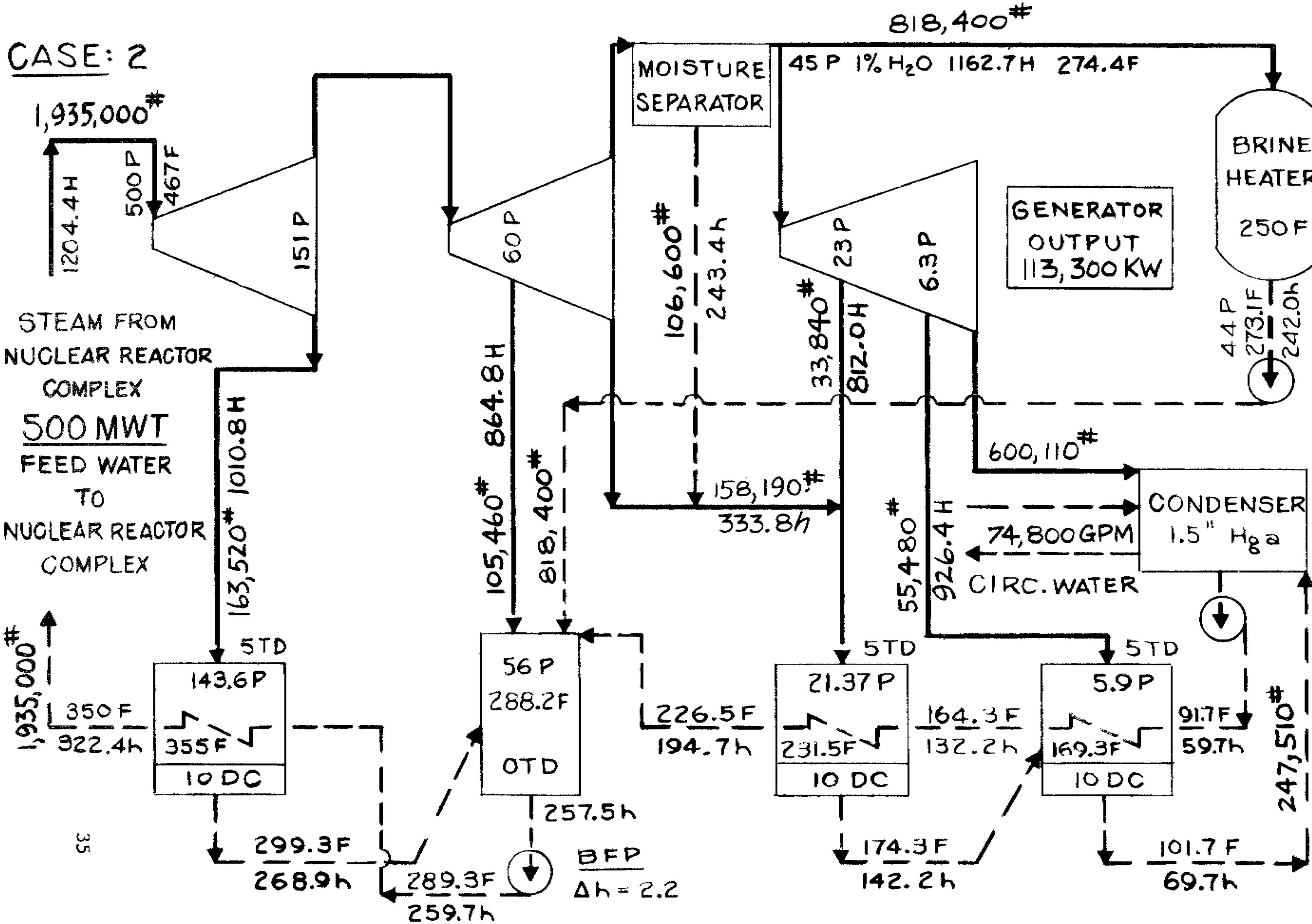

CASE: 2
1,935,000#
1204.4H
500P
467F
151P
STEAM FROM
NUCLEAR REACTOR
COMPLEX
500 MWT
FEED WATER
TO
NUCLEAR REACTOR
COMPLEX
163,520# 1010.8H
1,935,000#
350F
922.4h
143.6P
355F
10DC
5TD
299.3F
268.9h
289.3F
259.7h
60P
105,460# 864.8H
818,400#
56P
288.2F
0TD
257.5h
BFP
Δh = 2.2
MOISTURE
SEPARATOR
818,400#
45P 1% H2O 1162.7H 274.4F
106,600# 243.4h
158,190#
333.8h
226.5F
194.7h
23P
6.3P
33,840# 812.0H
21.37P
231.5F
10DC
5TD
164.3F
132.2h
174.3F
142.2h
GENERATOR
OUTPUT
113,300 KW
55,480# 926.4H
5.9P
169.3F
10DC
5TD
91.7F
59.7h
101.7F
69.7h
BRINE
HEATER
250F
44P 273.1F 242.0h
600,110#
CONDENSER
1.5" Hg a
74,800 GPM
CIRC. WATER
247,510#

FIGURE 21

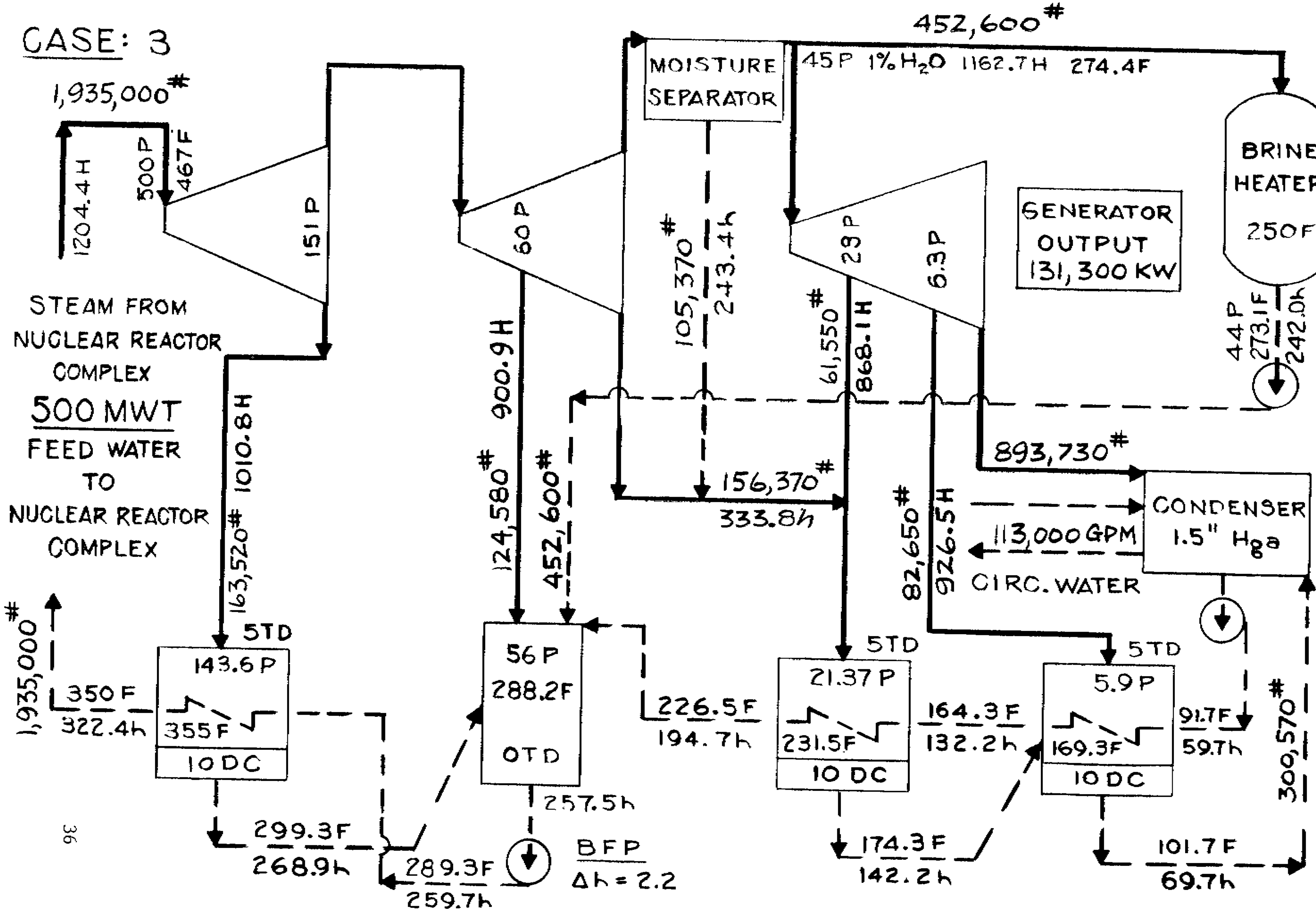

CASE: 3
1,935,000#
1204.4 H
500 P
467 F
151 P
STEAM FROM
NUCLEAR REACTOR
COMPLEX
500 MWT
FEED WATER
TO
NUCLEAR REACTOR
COMPLEX
1010.8 H
163,520#
60 P
900.9 H
124,580#
452,600#
MOISTURE
SEPARATOR
452,600#
45 P 1% H_2O 1162.7 H 274.4 F
105,370#
243.4h
23 P
6.3 P
61,550#
868.1 H
GENERATOR
OUTPUT
131,300 KW
BRINE
HEATER
250 F
4.4 P
273.1 F
242.0h
156,370#
333.8h
893,730#
82,650#
926.5 H
CONDENSER
1.5" Hga
113,000 GPM
CIRC. WATER
300,570#
1,935,000#
350 F
322.4h
5TD
143.6 P
355 F
10 DC
299.3 F
268.9h
289.3 F
259.7h
56 P
288.2 F
0TD
257.5h
BFP
Δh = 2.2
226.5 F
194.7h
5TD
21.37 P
231.5 F
10 DC
174.3 F
142.2h
164.3 F
132.2h
5TD
5.9 P
169.3 F
10 DC
91.7 F
59.7h
101.7 F
69.7h

FIGURE 22

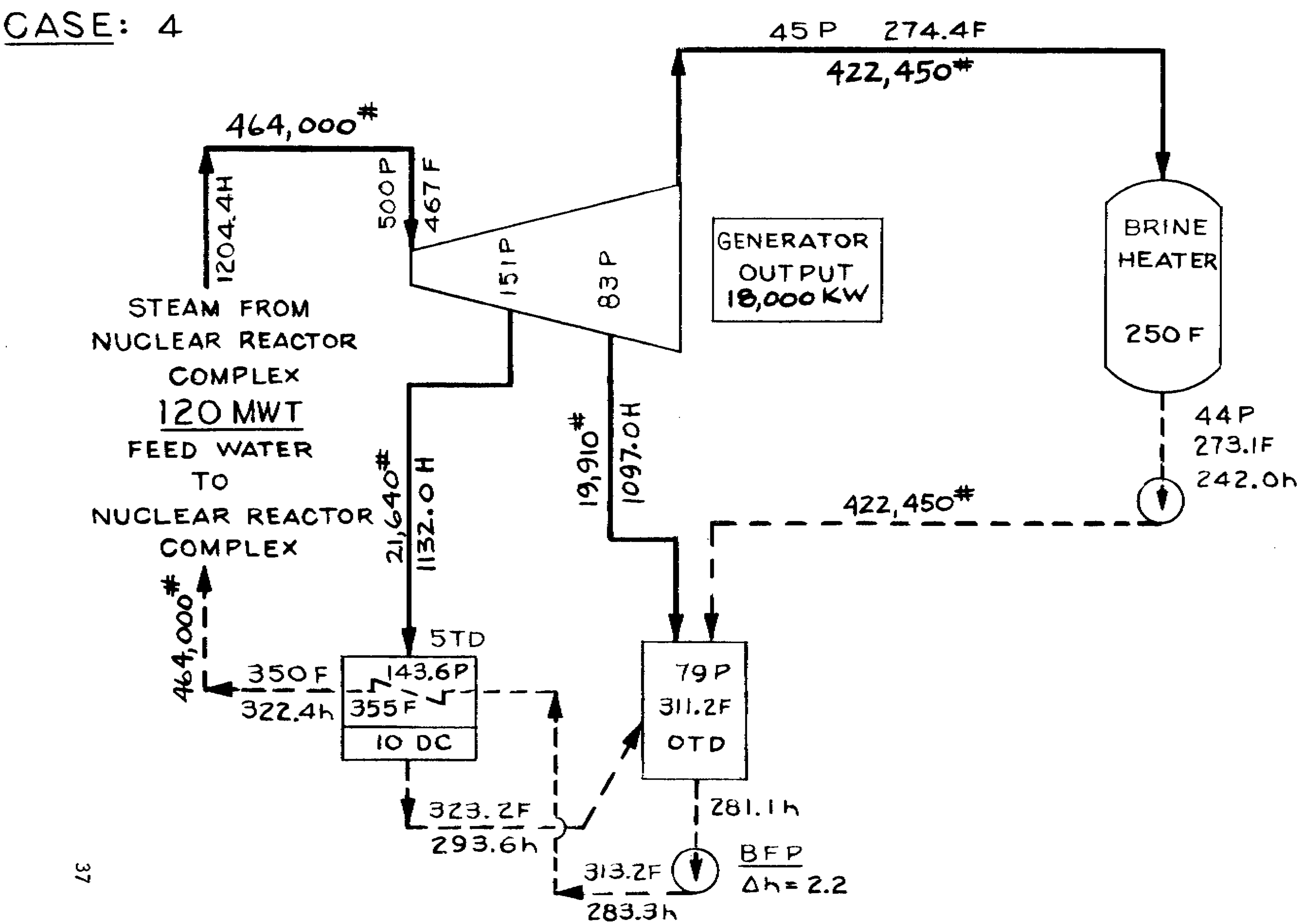

CASE: 4
45 P 274.4F
422,450#
464,000#
1204.4H
500 P
467 F
151 P
83 P
GENERATOR
OUTPUT
18,000 KW
BRINE
HEATER
250 F
STEAM FROM
NUCLEAR REACTOR
COMPLEX
120 MWT
FEED WATER
TO
NUCLEAR REACTOR
COMPLEX
44 P
273.1F
242.0h
422,450#
19,910#
1097.0H
21,640#
1132.0 H
464,000#
5TD
350 F
322.4h
143.6P
355 F
10 DC
79 P
311.2F
OTD
323.2F
293.6h
281.1h
BFP
Δh = 2.2
313.2F
283.3h

FIGURE 23

CASE: 5

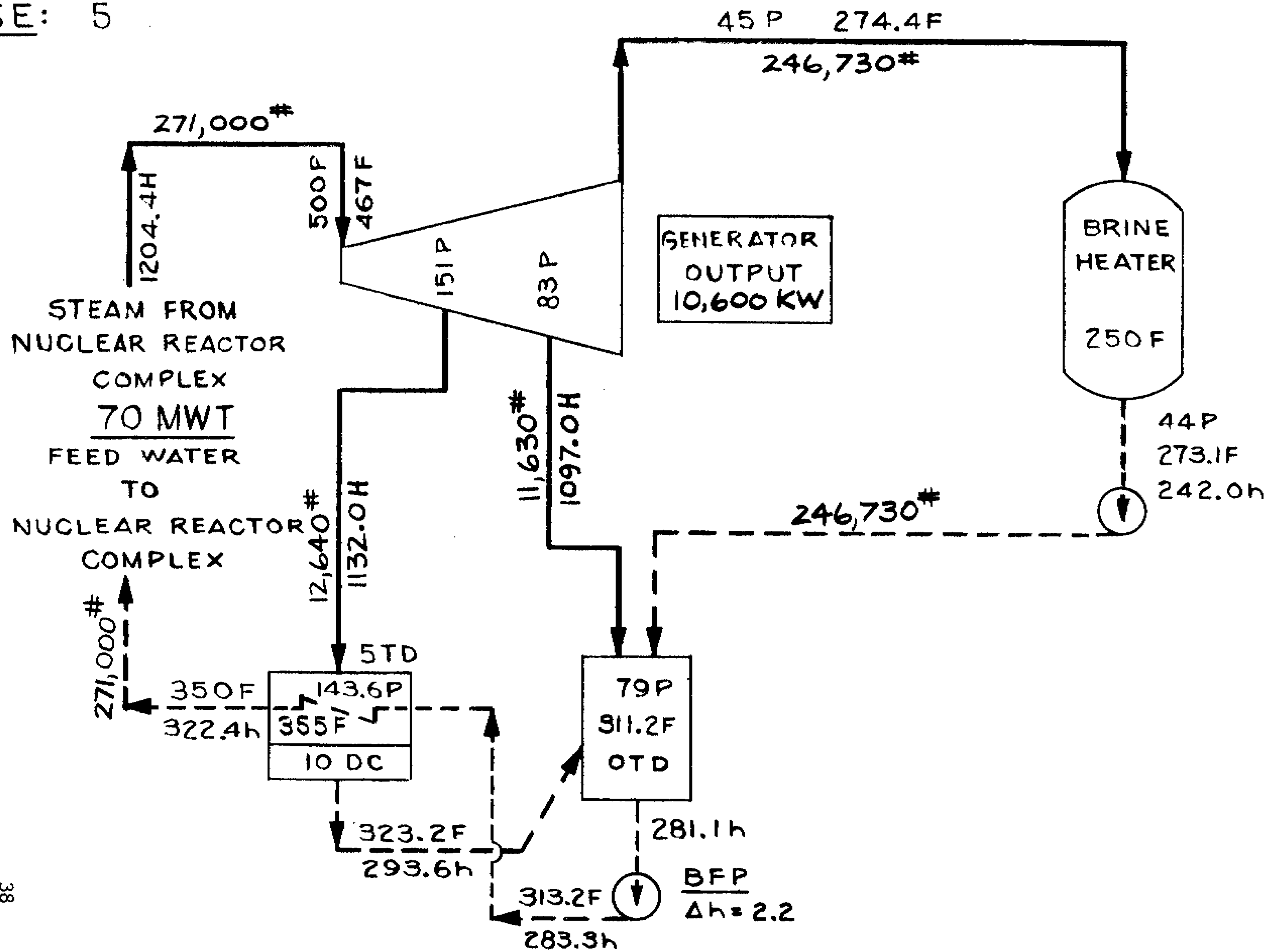


FIGURE 24

CASE: 6

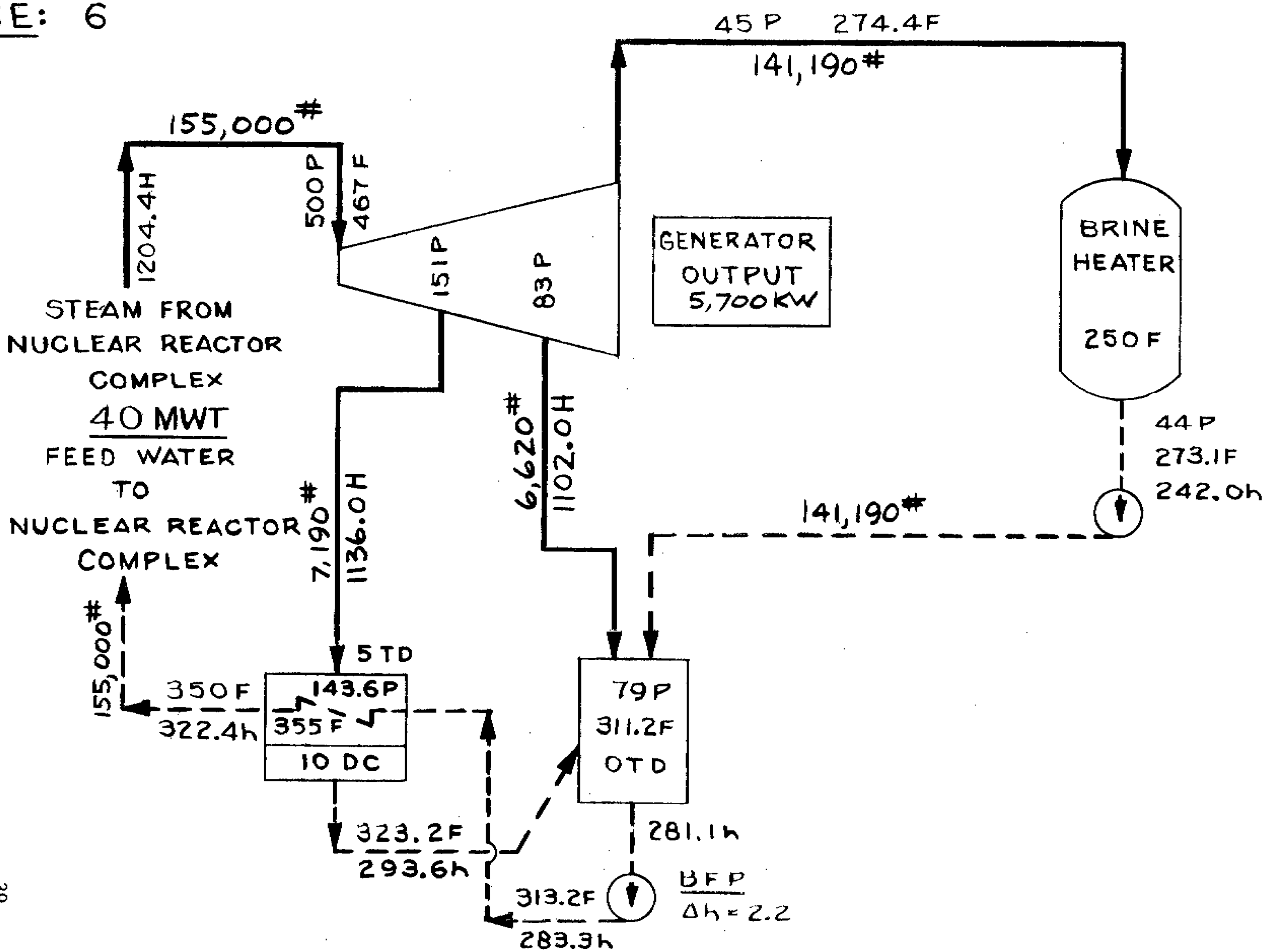


FIGURE 25

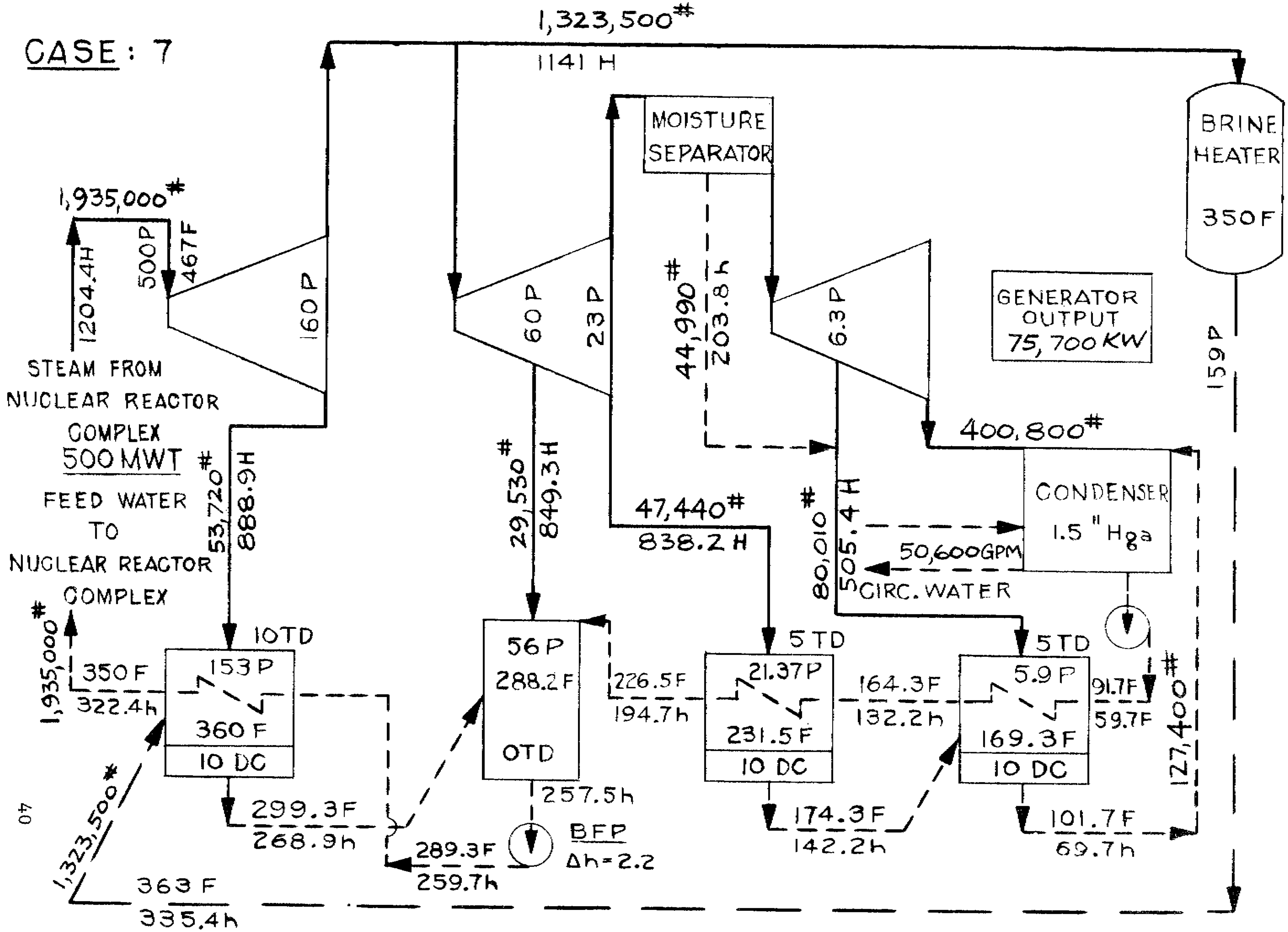

CASE: 7
1,323,500#
1141 H
MOISTURE SEPARATOR
BRINE HEATER
350F
1,935,000#
500P
467F
1204.4H
160P
60P
23P
44,990#
203.8h
6.3P
GENERATOR OUTPUT
75,700 KW
159P
STEAM FROM
NUCLEAR REACTOR
COMPLEX
500 MWT
FEED WATER
TO
NUCLEAR REACTOR
COMPLEX
53,720#
888.9H
29,530#
849.3H
47,440#
838.2H
80,010#
505.4H
400,800#
CONDENSER
1.5" Hga
50,600GPM
CIRC. WATER
1,935,000#
350F
322.4h
10TD
153P
360F
10 DC
56P
288.2F
OTD
257.5h
226.5F
194.7h
5TD
21.37P
231.5F
10 DC
164.3F
132.2h
5TD
5.9P
169.3F
10 DC
91.7F
59.7F
127,400#
299.3F
268.9h
289.3F
259.7h
BFP
Δh=2.2
174.3F
142.2h
101.7F
69.7h
1,323,500#
363F
335.4h

FIGURE 26

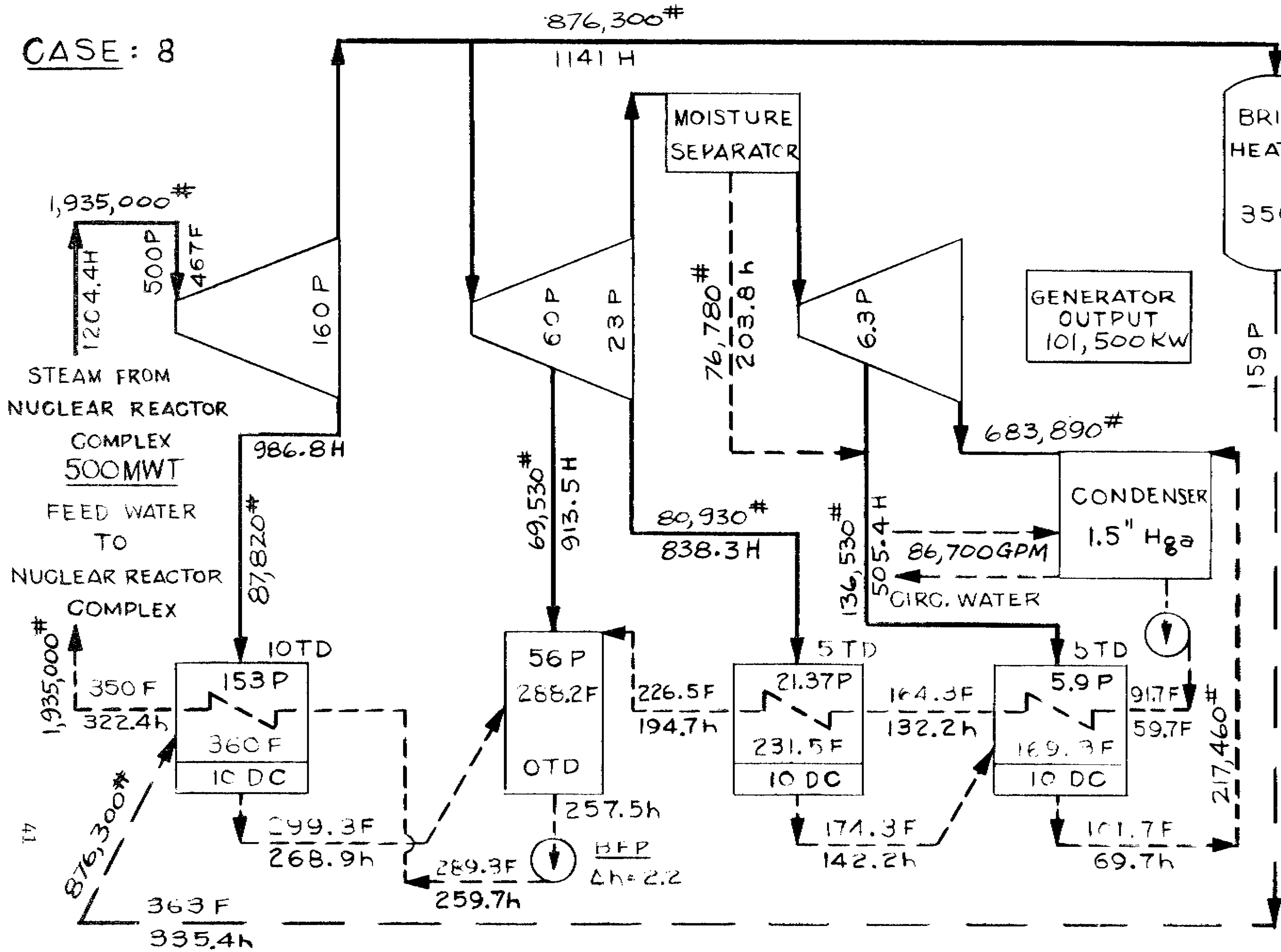

CASE: 8
876,300#
1141 H
MOISTURE SEPARATOR
BRINE HEATER
350 F
1,935,000#
1204.4H
500P
467F
160 P
60 P
23 P
76,780#
203.8 h
6.3P
GENERATOR OUTPUT 101,500 KW
159 P
STEAM FROM NUCLEAR REACTOR COMPLEX
500MWT
986.8H
683,890#
69,530#
913.5 H
80,930#
838.3 H
136,530#
505.4 H
CONDENSER
1.5" Hga
86,700 GPM
CIRC. WATER
FEED WATER TO NUCLEAR REACTOR COMPLEX
87,820#
1,935,000#
10TD
350 F
322.4h
153 P
360 F
10 DC
56 P
288.2F
OTD
226.5 F
194.7h
5 TD
21.37P
231.5 F
10 DC
164.3F
132.2h
5 TD
5.9 P
169.3 F
10 DC
91.7F
59.7F
217,460#
876,300#
299.3F
268.9h
257.5h
289.3F
259.7h
BFP
Δh=2.2
174.3 F
142.2h
101.7 F
69.7h
363 F
335.4h

FIGURE 27

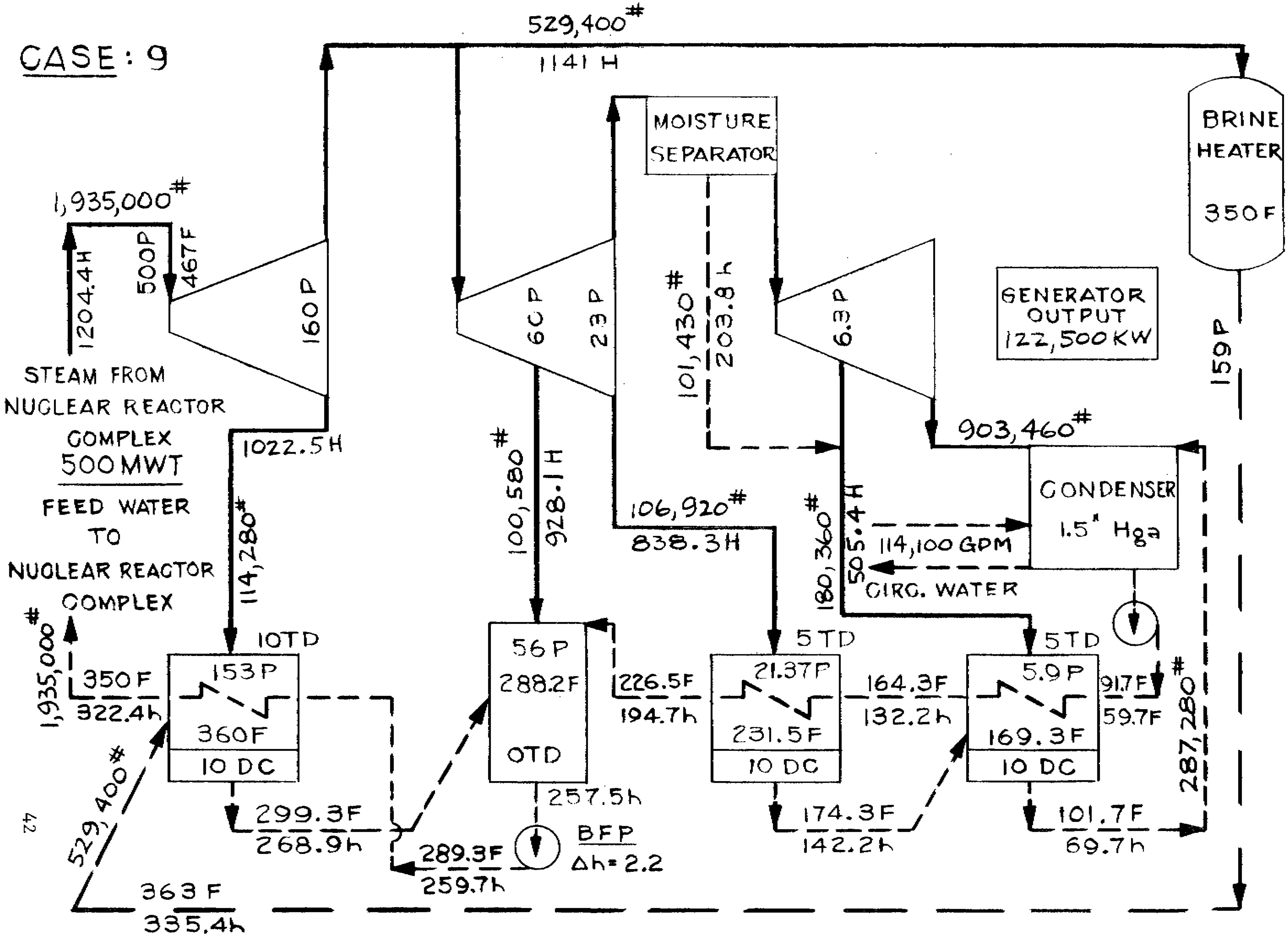

CASE: 9
529,400#
1141 H
MOISTURE SEPARATOR
BRINE HEATER
350 F
1,935,000#
500P
467F
1204.4H
160P
6CP
23P
101,430#
203.8h
6.3P
GENERATOR OUTPUT 122,500 KW
159P
STEAM FROM NUCLEAR REACTOR COMPLEX
500 MWT
1022.5H
100,580#
928.1H
903,460#
FEED WATER TO NUCLEAR REACTOR COMPLEX
114,280#
106,920#
838.3H
180,360#
505.4H
CONDENSER
1.5" Hga
114,100 GPM
CIRC. WATER
1,935,000#
10TD
56P
288.2F
OTD
5TD
5TD
350F
322.4h
153P
360F
10 DC
226.5F
194.7h
21.37P
231.5F
10 DC
164.3F
132.2h
5.9P
169.3F
10 DC
91.7F
59.7F
287,280#
529,400#
299.3F
268.9h
257.5h
BFP
Δh=2.2
174.3F
142.2h
101.7F
69.7h
289.3F
259.7h
363 F
335.4h

FIGURE 28

CASE: 10

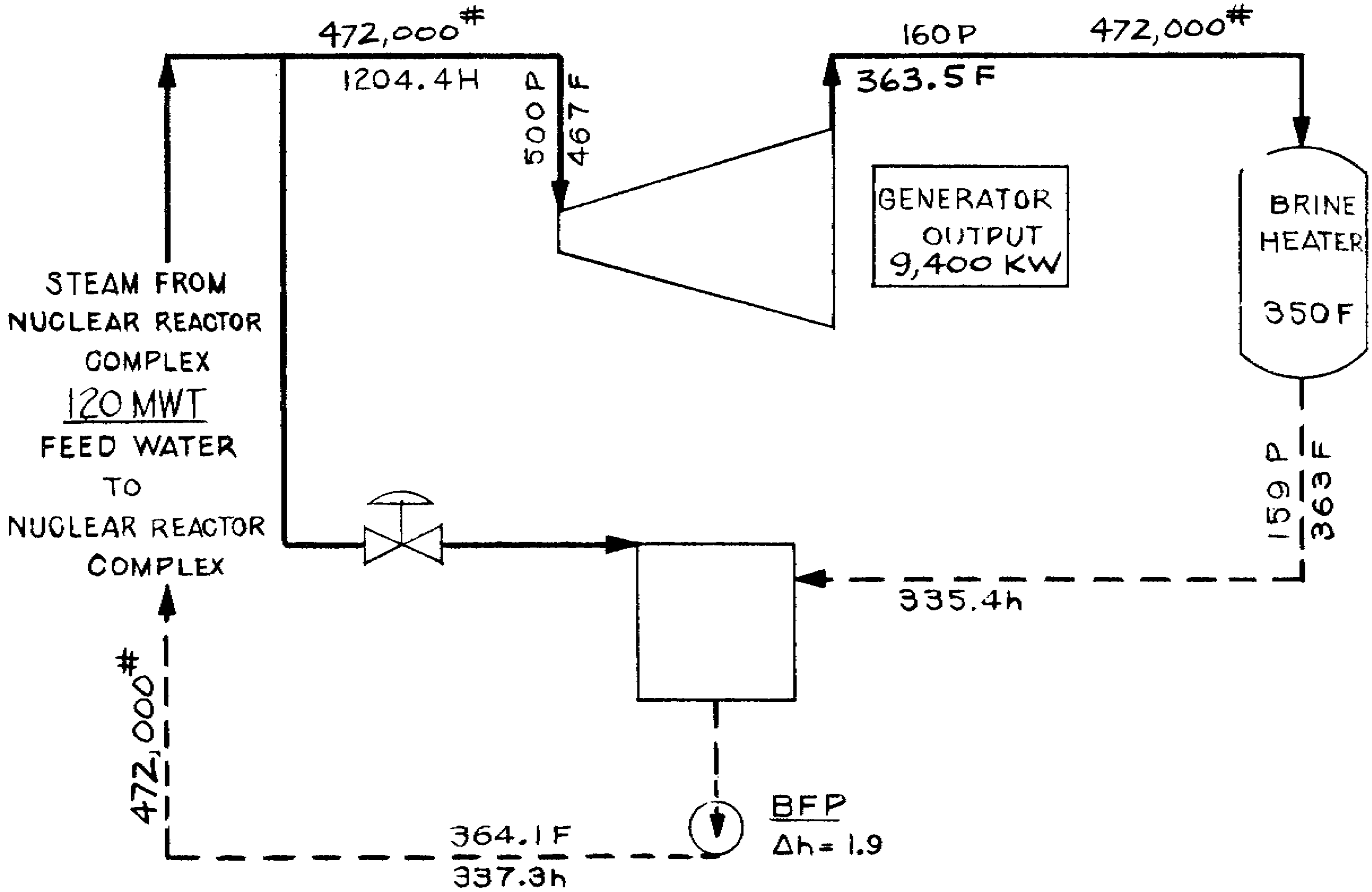


FIGURE 29

PARAMETRIC COST STUDIES

CASE: 11

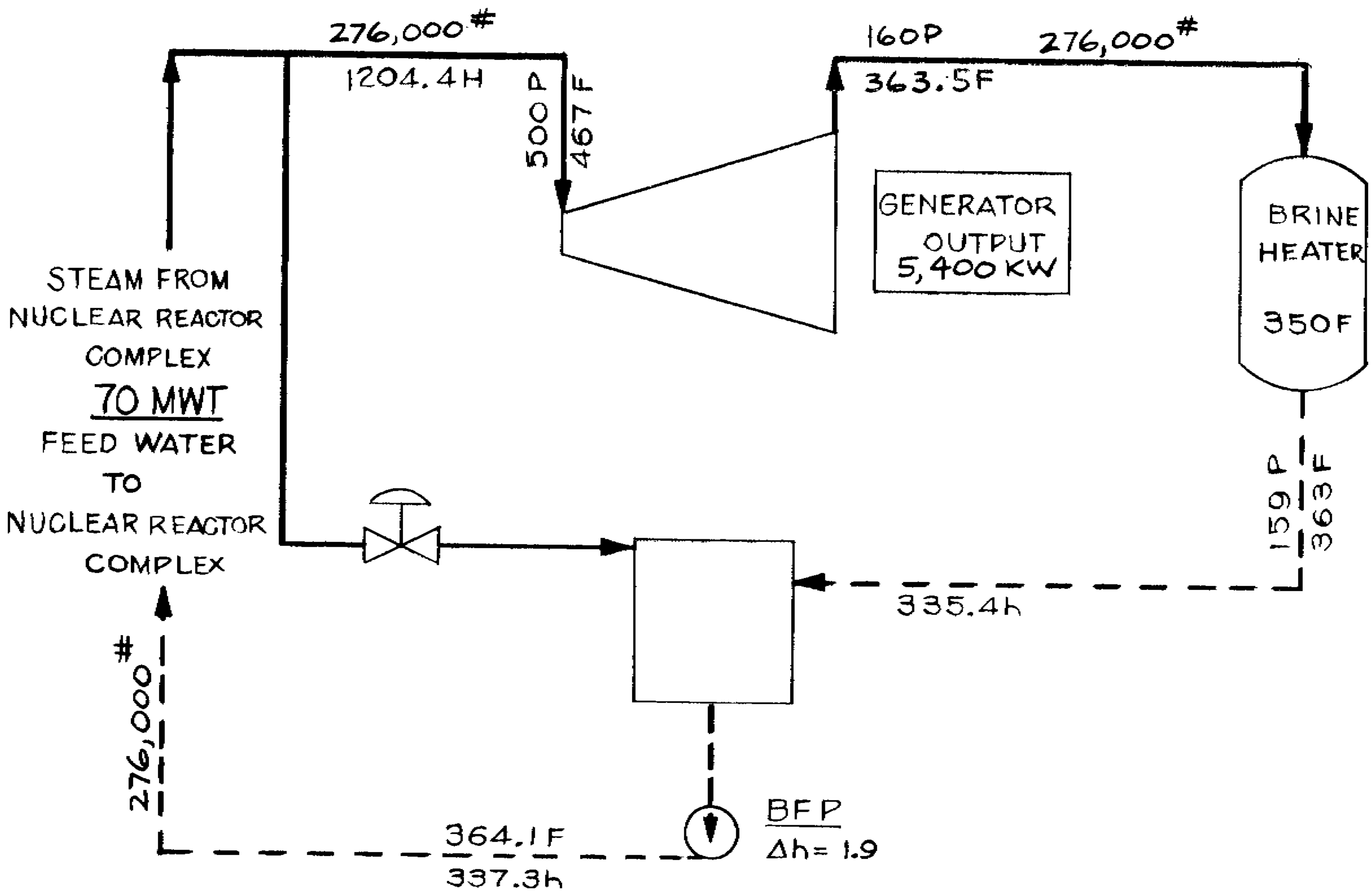


FIGURE 30

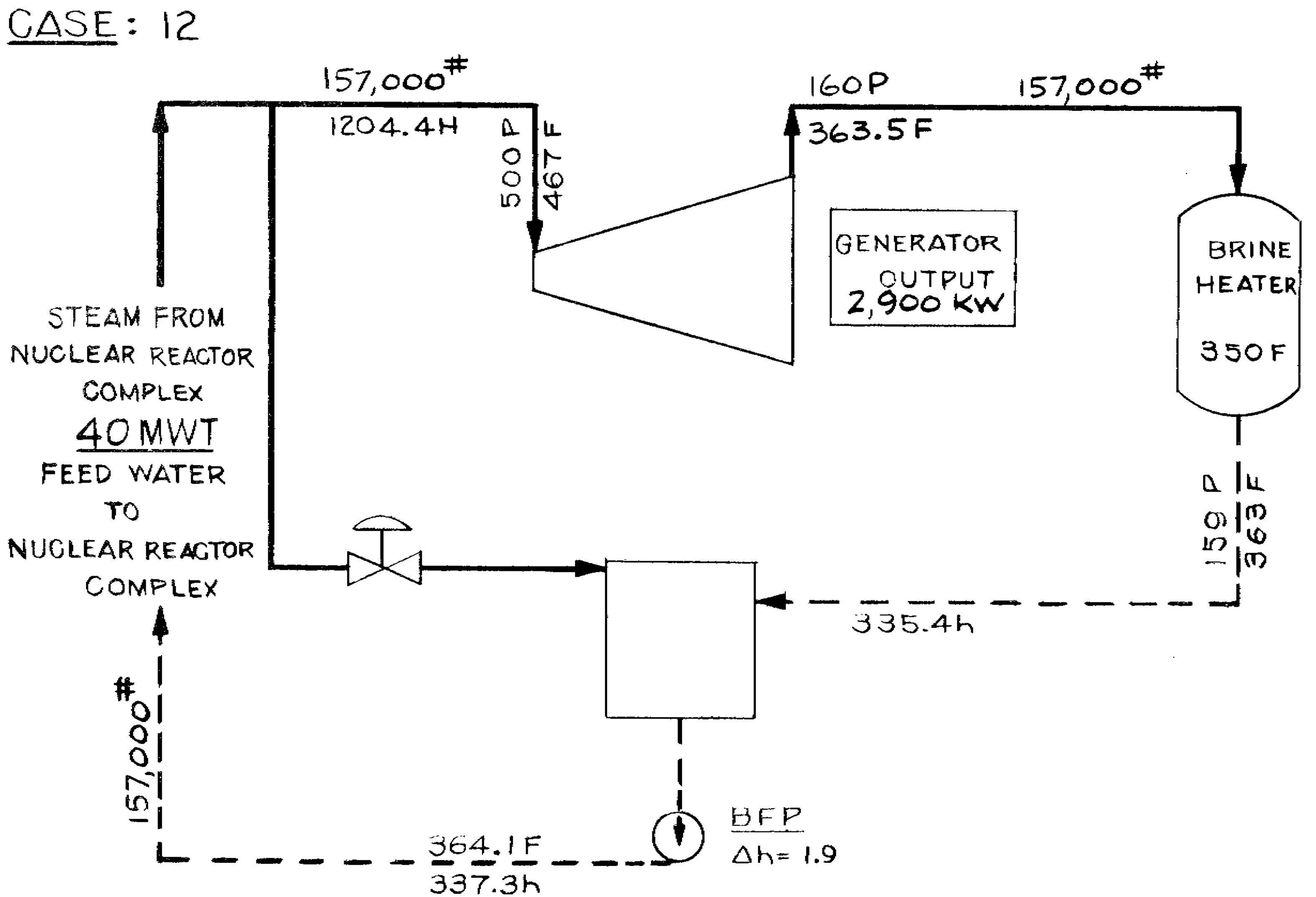

CASE: 12
157,000#
1204.4H
500 P
467 F
160P
363.5F
157,000#
GENERATOR OUTPUT 2,900 KW
BRINE HEATER
350F
STEAM FROM NUCLEAR REACTOR COMPLEX
40 MWT
FEED WATER TO NUCLEAR REACTOR COMPLEX
159 P
363 F
335.4h
157,000#
BFP
Δh= 1.9
364.1F
337.3h

FIGURE 31

a turbine generator. The following conditions were used for each case:

Case No.	13	14
Steam Pressure from Reactor Complex - psia (saturated)	195.8	160
Feedwater Temperature to Reactor Complex - °F	273.1	363

Table 3 summarizes performance data for all nuclear plants studied, Cases 1 through 14.

Turbines selected for Cases 1, 2, 3, 7, 8 and 9 utilize subatmospheric or condensing exhaust sections since the steam produced by the 500-MWt reactor plants exceeds the steam required for 50-, 35- and 20-million-gallons-per-day water production. This excess steam is utilized in the low-pressure turbine sections for electric generation. Estimated performance for condensing turbines was based on use of moisture-extracting buckets together with an external moisture separator in order to control internal turbine moisture to reasonable levels.[1,2]*

The remaining cases, which are shown in Figures 32 through 37 and incorporate turbine generators, were based on noncondensing units with the entire turbine exhaust flow used for water conversion. Turbine performance for noncondensing units was based on manufacturers' published handbook data.[3,4]

Heat balance calculations were based on an estimated performance ratio for each specific case. Following determination of unit costs, the calculated performance ratio for the optimized desalination plant was obtained by interpolation from the computer program results and compared to the initially estimated performance ratio. Several iterations were required for both cycle performance and unit costs determinations in order to obtain favorable agreement between estimated and calculated performance ratios.

Table 3 presents both the calculated performance ratio and the initially assumed performance ratio for each nuclear case studied. Comparison of these two items indicates good agreement for all cases with a maximum deviation of 0.9 for Case 3.

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* Superscript numbers denote references listed in the Appendix.

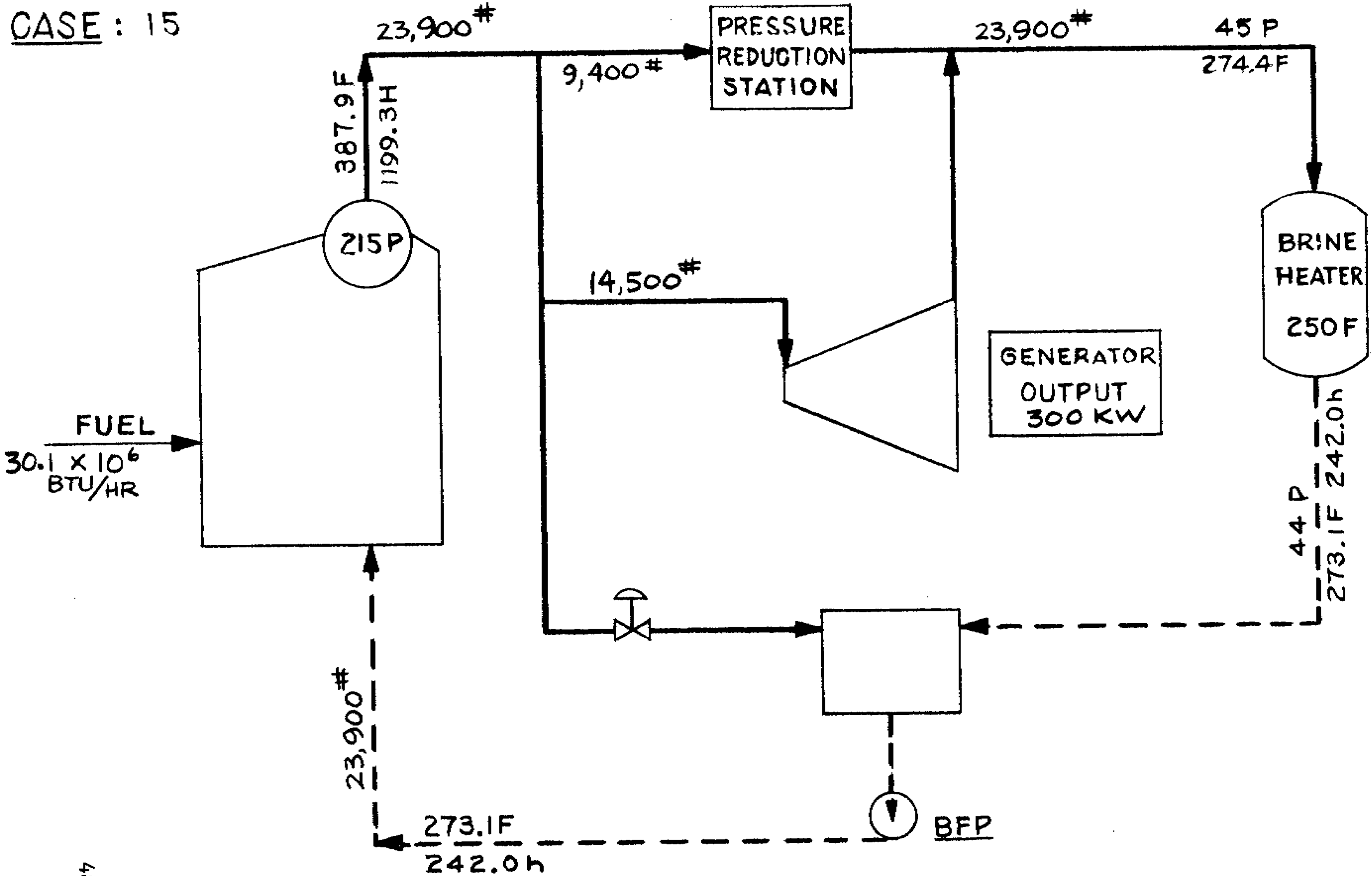


FIGURE 32

PARAMETRIC COST STUDIES

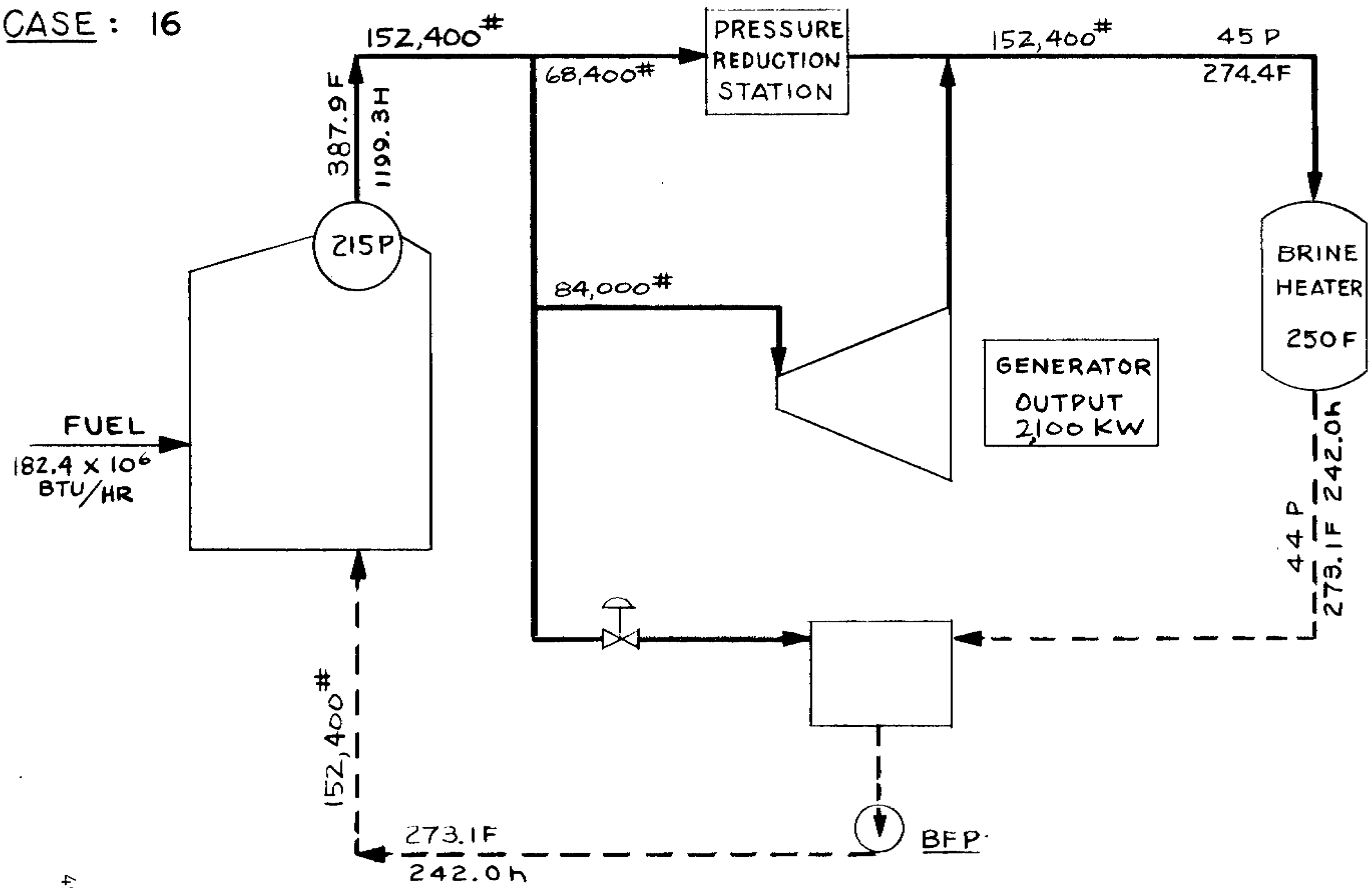


FIGURE 33

PARAMETRIC COST STUDIES

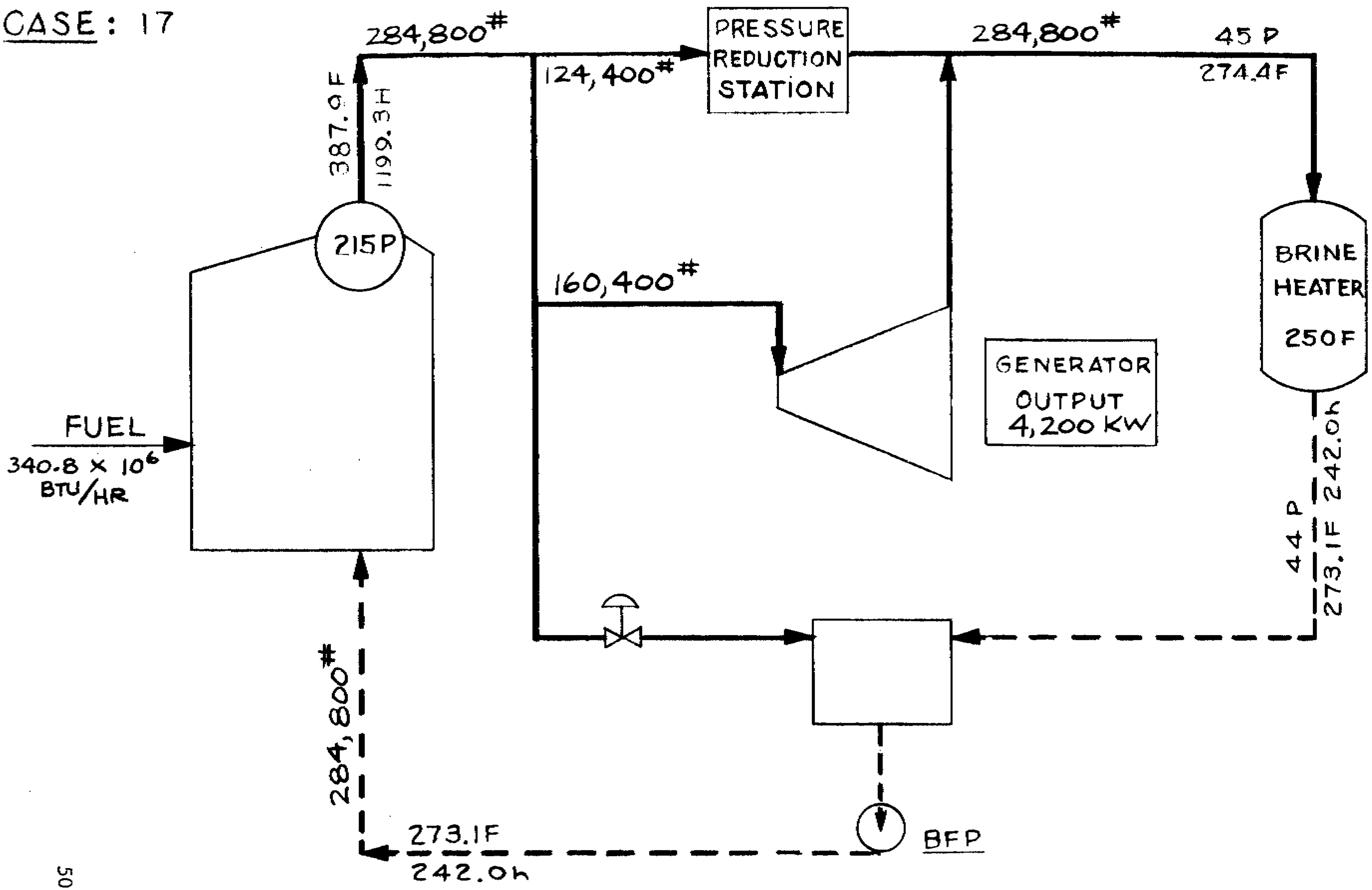

CASE: 17
284,800#
387.9F
1199.3H
215P
124,400#
PRESSURE
REDUCTION
STATION
284,800#
45 P
274.4F
160,400#
BRINE
HEATER
250F
GENERATOR
OUTPUT
4,200 KW
FUEL
340.8 × 10^6
BTU/HR
242.0h
44 P
273.1F
284,800#
273.1F
242.0h
BFP

FIGURE 34

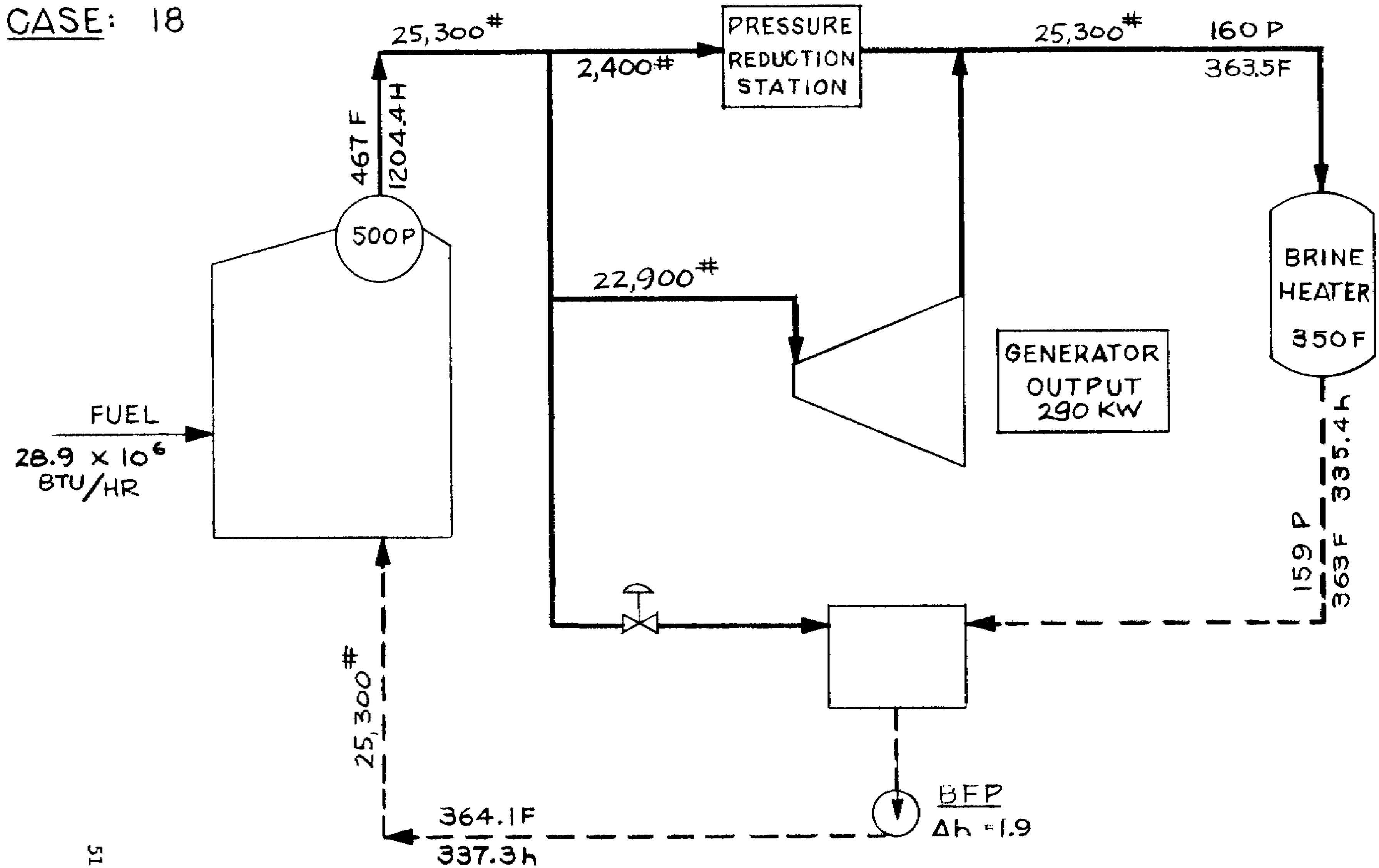

CASE: 18
25,300#
2,400#
PRESSURE
REDUCTION
STATION
25,300#
160 P
363.5F
467 F
1204.4H
500P
22,900#
BRINE
HEATER
350F
GENERATOR
OUTPUT
290 KW
FUEL
28.9 x 10^6
BTU/HR
335.4h
159 P
363 F
25,300#
BFP
Δh = 1.9
364.1F
337.3h

FIGURE 35

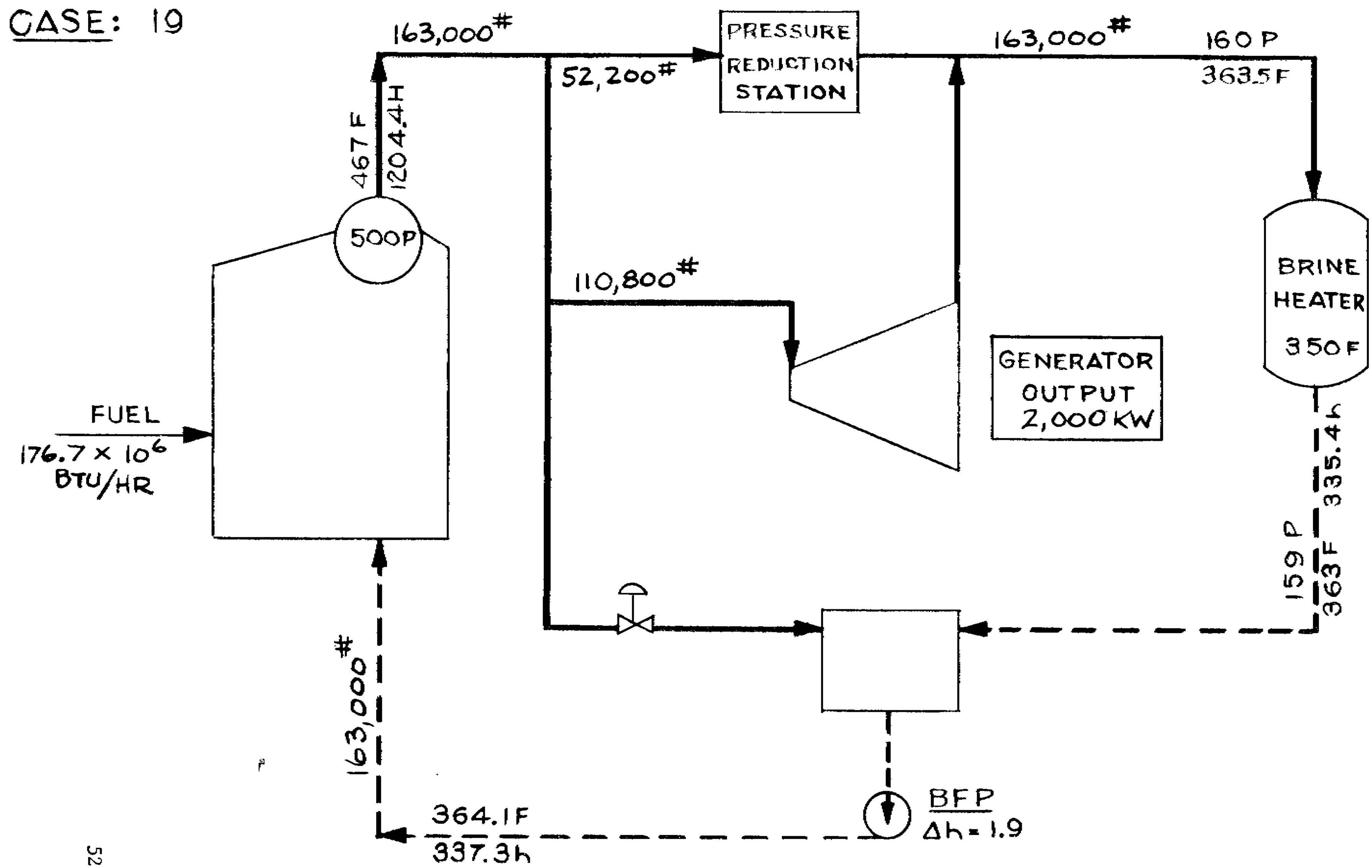
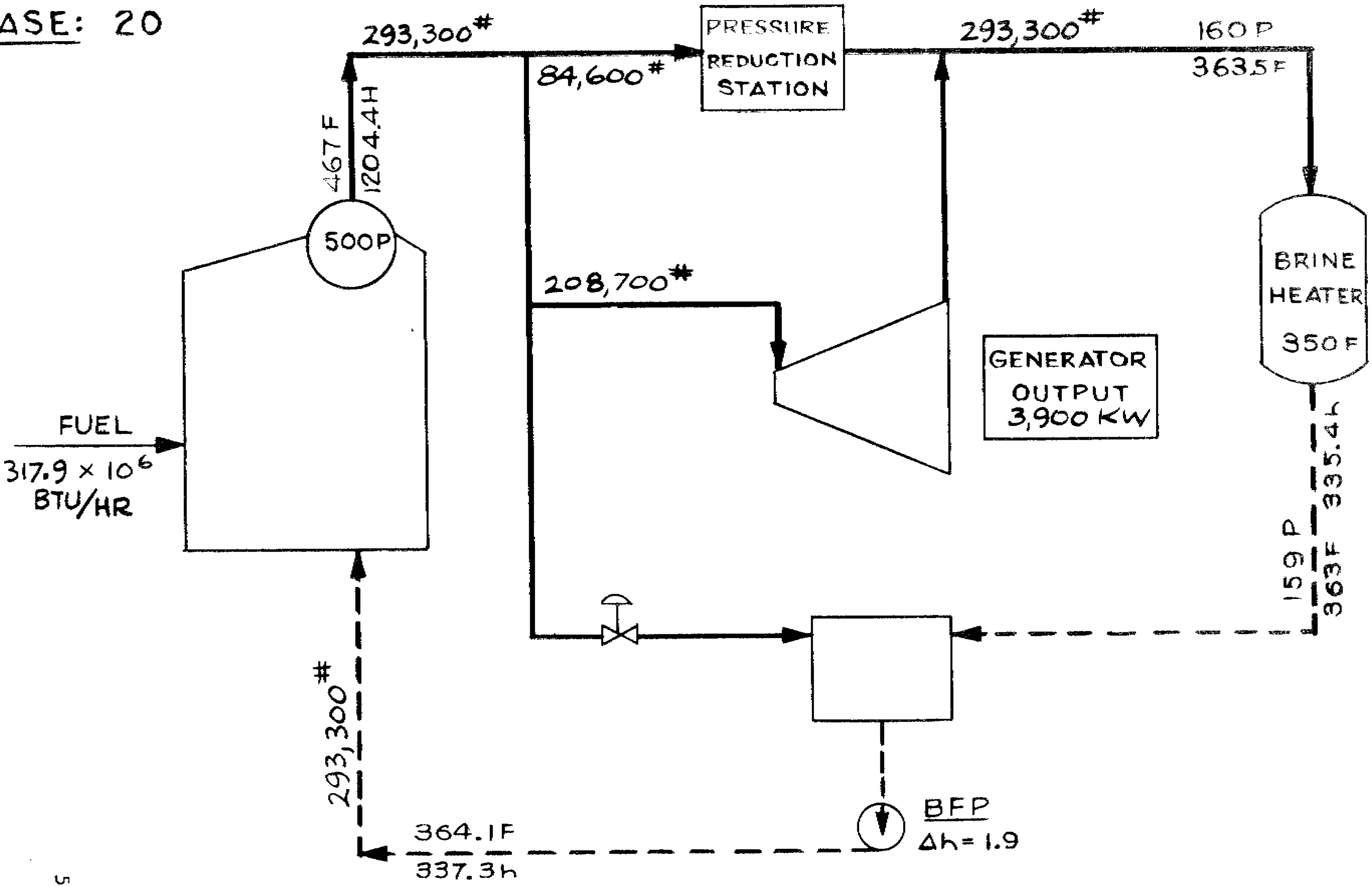

CASE: 19
163,000#
52,200#
PRESSURE REDUCTION STATION
163,000#
160 P
363.5 F
467 F
1204.4 H
500P
110,800#
BRINE HEATER
350 F
GENERATOR OUTPUT 2,000 KW
FUEL
176.7 × 10^6 BTU/HR
335.4 h
159 P
363 F
163,000#
BFP
Δh = 1.9
364.1 F
337.3 h

FIGURE 36

CASE: 20



PARAMETRIC COST STUDIES

FIGURE 37

A third performance ratio identified as "Actual Performance Ratio" is also reported on Table 3. This item is based on calculated steam conditions at the brine heater, whereas the previously discussed performance ratios are based on saturated steam at the brine heater. These parameters are discussed in detail in the section on computer runs.

b. Fossil-Fuel Plants

Selection of cycle conditions for fossil-fuel plants was based on the required water production of 1, 7 and 14 million gallons per day and an evaluation of major equipment costs. All cases were based on electric generation sufficient to supply the demands of both the desalination and steam-turbine plants. By-product electric generation was not considered.

The calculating procedure described above for nuclear plants was used for determining cycle performance and sizing major equipment. In addition, separate calculations were performed for 20, 30 and 40 cents per million Btu fuel costs for each of the six cases studied.

All fossil-fuel cases utilize gas-fired boilers producing saturated steam, and noncondensing turbine generators with the entire turbine exhaust flow used for water conversion. Cases 15 and 18 produce 1,000,000 gallons of water per day and utilize package boilers with an estimated efficiency of 76 percent. The remaining cases were based on standard boilers employing air heaters with an estimated efficiency of 80 percent.

Table 4 summarizes performance data and results at 20, 30 and 40 cents per million Btu fuel costs for each of the six fossil-fuel cases. For each case and fuel cost, three performance ratios in accordance with the preceding definitions have been tabulated. Comparison of the calculated performance ratios and the initially estimated performances ratios which formed the basis of all costs estimates and performance indicates good agreement with a maximum deviation of 0.3 for Case 15.

Heat balances are included for the six fossil-fuel cases based on 30 cents per million Btu fuel cost.

c. Auxiliary Power

Detailed analysis of electric power demands for the various desalination and nuclear plants were not performed.

Based on Bechtel's Study[5] the following power demands were allocated to the desalination plants:

Brine Temperature - °F	KW per Million Gallon Production
250	275
350	245

Additional investigation of several published studies resulted in the data shown on Figure 19 and reasonably substantiates the above parameters.

Auxiliary power demands for the dual-purpose reactors are based on data on page 21 of Henly & Kouts.[6] According to this reference the PWR requires 9 percent of the generated output, of which 2 percent is for feedwater pumps which are in the turbine cycle. Applying an efficiency of 30 percent to the remaining 7 percent results in auxiliary requirements which are 2.1 percent of the reactor thermal rating. For this study the value was rounded off to 2.0 percent. The process reactors considered for Cases 13 and 14 have lower velocities in the primary system and hence lower pumping and auxiliary power requirements. Those used here were obtained by evaluating data in report SL-1767.[7] The resulting electric power demands used for the various nuclear reactor plants are:

Reactor Rating MWt	Reactor Auxiliary Power KW
500	10,000
120	2,400
70	1,400
40	800
40 (Process Reactor) (Cases 13 and 14)	100

Auxiliary power required for each turbine cycle was based on the summation of total calculated pumping power indicated on the heat balance for each case and an allowance of 5 percent for miscellaneous consumption.

Table 3 summarizes gross generator output, auxiliary power required for the desalination and reactor-turbine plants, total auxiliary power demands and net electric power available for sale for each nuclear case.

Auxiliary power requirements for each fossil-fuel case were based on the summation of calculated boiler feed pump and an assumed allowance for boiler electric power demands. Gross generator output and desalination plant auxiliary power are stated on Table 4 for all fossil-fuel cases.

d. Cost Estimates

(1) Pumping Cost for Saline Water

Inasmuch as no particular site was specified for this study, common factors based on our existing water pumping installations were used and applied to all phases as noted in Table 5. Where condensing turbines were used the circulating water costs were included in the turbogenerator account, No. 323, and the effluent from the condensers was used as input to the water desalination plant. Under this procedure the cost of sea water feed was lower than for direct pumping from the sea. If necessary, any additional water was pumped directly from the sea.

The unit pumping costs used in Table 5 were developed as follows:

Unit Cost for Sea Water Supply

Item	$/GPM
Pumps (vertical - axial flow)	1.25
Motors - use 20 psi head then hp = .014 gpm for motors use 40/hp complete	.56
Intake Structure including Screens, Wash Pumps use $2.00 For Discharge Structure add $1.00	3.00
Piping	3.19
Basic Unit Price for Salt Water Supply	8.00

TABLE 5

PARAMETRIC COST STUDIES
CAPITAL COSTS FOR PUMPING INSTALLATIONS

Case No.	Product Water MMGPD	Total Sea Water Required GPM	Water From Turbogenerator Plant Condenser GPM	Remaining Water To Be Supplied From Sea GPM	Estimated Capital Cost* of Pumping System Dollars
1	50.0	84,000	39,700	44,300	493,400
2	35.0	58,900	74,800	-	206,200
3	20.0	33,600	111,300	-	117,600
4	19.6	33,000	-	33,000	264,000
5	11.6	19,600	-	19,600	156,800
6	7.0	11,800	-	11,800	94,400
7	50.0	84,000	50,600	33,400	444,300
8	35.0	58,900	86,700	-	206,200
9	20.0	33,600	114,100	-	117,600
10	25.3	42,600	-	42,600	340,800
11	14.3	24,100	-	24,100	192,800
12	7.8	13,200	-	13,200	105,600
13	7.6	12,800	-	12,800	102,400
14	8.6	14,500	-	14,500	116,000
15 (A, B, C)	1.0	1,700	-	1,700	13,600
16 (A, B, C)	7.0	11,800	-	11,800	94,400
17 (A, B, C)	14.0	23,600	-	23,600	188,800
18	1.0	1,700	-	-	13,600
19	7.0	11,800	-	-	94,400
20	14.0	23,600	-	-	188,800

* Based on \$8.00/GPM for sea water pumps and \$3.50/GPM for circulating pumps.
See page 57 for breakdown.

Unit Cost for Reuse of Condenser Water

Item	$/GPM
Pumps (centrifugal)	.75
Motors	.56
Structures, Cut-ins, etc.	.54
Piping (shorter runs)	1.65
Total Unit Price for Condenser Reclaimed Water	3.50

(2) Turbogenerator Costs

Again since no site selection was made it was presumed that the plants would be oriented toward the source of sea water, and in the common site facilities such items as fences, roads, railroads and miscellaneous buildings were estimated on this basis. These costs were calculated based on the overall size of a combined plant and distributed equitably among nuclear, power and water portions of the overall plant as listed in Table 6.

Contact was made with turbine vendors in order to determine as closely as possible the basic cost of specific turbines. Other items were based on cost data from our files, coupled with the use of standard units such as dollars per kw, dollars per square foot, etc.

(3) Markups

This item indicates the required cost for design and engineering of the turbogenerator facility only, including field supervision, construction management, interest during construction and contingency. These factors vary based on our history of past and present construction costs with the exception of a contingency which in all cases was included at 10 percent.

The resulting cost figures are shown in Tables 7 and 8.

F. Desalination Plant

1. Description

The desalination plants in this study are similar to the Bechtel design[5] and utilize multistage flash evaporation for sea water purification. Principal equipment associated with the water plant includes the evaporators, brine heaters, air ejectors, condensers and associated pumps.

Evaporator shells are constructed of concrete for brine temperatures up to 250° F; steel shells are used for brine temperatures above 250° F. The use of concrete shells provides a considerable savings in cost over the use of steel shells.

Sea water intake is screened for removal of trash and fine debris. The intake is periodically injected with chlorine gas to prevent the growth of algae, barnacles and other marine life. Feedwater is treated with sulfuric acid to decompose carbonates before the water begins circulating in the condenser and brine heater system.

Following acidification, the feed is degasified in an open atmospheric tank. This partially removes CO_2 resulting from acidification, and reduces the load on the evaporator ejector system. The feedwater then flows through the condenser tubes in the heat rejection stages, which for all size plants are the two lowest pressure stages. After passing through the condenser tubes it is deaerated and mixed with the recycle brine leaving the last heat rejection stage.

The combined feed and brine is picked up by the recycle and blowdown pumps. The recycle pumps discharge recycle brine into the condensers of the heat recovery section where the stream recovers heat from condensation of the product water. The blowdown pumps discharge spent brine to a waste water channel for release to the sea.

The recycle brine flows through the heat recovery stages and discharges from the highest pressure stage. The recycle brine is then heated to the first stage operating temperature by condensing steam in the brine heaters, which are shell-and-tube-type heat exchangers. The hot recycle brine then flows into the first stage of the evaporator to begin a series of flashings. The brine flashes through stages of successively lower pressure in the heat recovery section to the heat rejection section.

Accumulations of noncondensible gasses are drawn from every sub-atmospheric stage through a steam ejector system. Pressure stages are vented to the atmosphere as required.

The product water is collected in an open stream within the evaporators. It is arranged to flash from stage to stage as a means of recovering sensible heat. It is finally pumped through sea water coolers for delivery as required.

The overall flow for the water plant is shown schematically in Figure 38.

2. Computer Runs

a. Cases Considered

Computer optimization of the desalination plant was performed primarily to determine capital costs and steam requirements for the optimized plants. The parametric study covered the following sets of conditions:

Brine heater exit temperature	- 250 and 350° F
Water production capacity	- 1, 20 and 54.5 mmgpd
Steam cost	- 20, 70 and 120¢/1000 lb
Power cost	- 3, 6.5 and 10 mills/kwhr

The cost of steam and power for a particular water plant depends upon the design of the associated reactor and turbine plants, Since the design of these plants proceeded simultaneously with the computer optimization, exact values for the cost of steam and power were not known at the time of the computer runs. Therefore, the steam and power costs listed above were selected to provide a range which was designed to cover subsequently calculated values.

The three water production rates used in the computer runs cover the required range of 1 to 50 mmgpd. While the upper limit on production rate has been set at 50 mmgpd, preliminary heat balance studies indicated that a 50-MWt reactor plant could supply sufficient steam to produce 54.5 mmgpd. Therefore, this was used as the upper limit on water production in the computer runs.

DESALINATION PLANT FLOWCHART

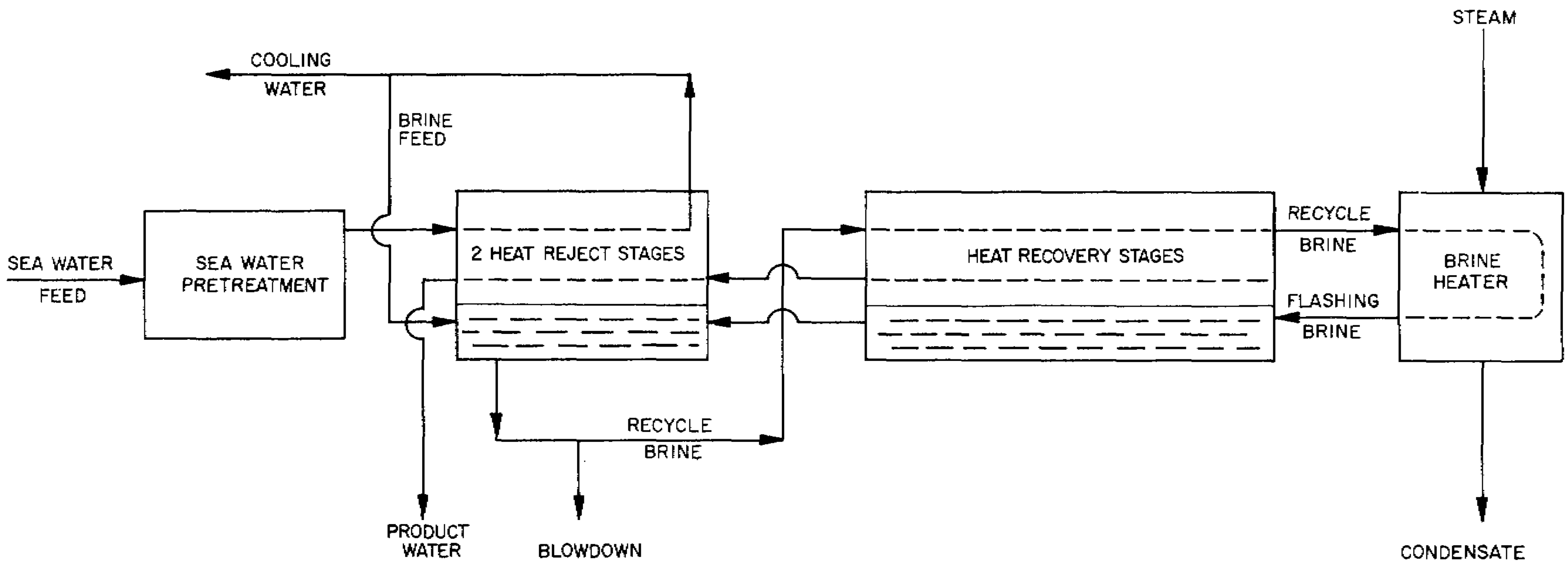


FIGURE 38

Runs were performed at brine heater exit temperatures of 250° F and 350° F. A total of 54 computer runs were made to cover all combinations of the four items listed above. These constitute the basic independent parameters for each case. Table 9 lists the production rate, power cost, steam cost and brine heater brine exit temperature for each computer run.

b. Conditions Used

The optimization of the desalination plant was performed on an IBM 7090 using the computer program developed by the Bechtel Corp.[5] Table 10 lists those items of input which are constant for all runs. Sea water temperature is fixed by the design criteria. The concentration ratio was chosen as 1.7, since the cost of water is minimal and is essentially independent of small variations in brine concentration in this range. All other data shown in Table 10 are reasonable estimates based in part on Reference (5).

Table 11 lists those items of input which vary from run to run. A steam pressure of 45 psia (274.4° F saturation temperature) has been selected for all cases with a brine heater temperature of 250° F; a steam pressure of 160 psia (363.5° F saturation temperature) has been chosen for a brine heater temperature of 350° F. While an optimization of steam temperature could be made based upon the costs of steam, power and brine heater surface, it was felt that the pressures chosen represent reasonable values for the purposes of this study.

The condenser tube lengths and surface and equipment costs listed in Table 11 are based upon preliminary sizing of the condensers and brine heaters. Items such as internal piping and baffles, and insulation, lining and paint are included in the concrete and steel vessel costs.

3. Computer Results

A complete set of computer output data has been submitted to the Office of Saline Water and, therefore, is not reproduced in this report. However, a summary of the computer output from the economic section of the program is presented in Table 12, listing the output data

PARAMETRIC COST STUDIES TABLE 9

COMBINATIONS OF INDEPENDENT PARAMETERS FOR COMPUTER RUNS

Run No.	1	2	3	4	5	6	7	8	9	10
Production Rate, mmgpd	1	1	1	1	1	1	1	1	1	1
Power Cost, mills/kwhr	3	3	3	3	3	3	6.5	6.5	6.5	6.5
Steam Cost, ¢/1000 lb	20	70	120	20	70	120	20	70	120	20
Brine Heater Temperature, °F	250	250	250	350	350	350	250	250	250	350
Run No.	11	12	13	14	15	16	17	18	19	20
Production Rate, mmgpd	1	1	1	1	1	1	1	1	20	20
Power Cost, mills/kwhr	6.5	6.5	10	10	10	10	10	10	3	3
Steam Cost, ¢/1000 lb	70	120	20	70	120	20	70	120	20	70
Brine Heater Temperature, °F	350	350	250	250	250	350	350	350	250	250
Run No.	21	22	23	24	25	26	27	28	29	30
Production Rate, mmgpd	20	20	20	20	20	20	20	20	20	20
Power Cost, mills/kwhr	3	3	3	3	6.5	6.5	6.5	6.5	6.5	6.5
Steam Cost, ¢/1000 lb	120	20	70	120	20	70	120	20	70	120
Brine Heater Temperature, °F	250	350	350	350	250	250	250	350	350	350
Run No.	31	32	33	34	35	36	37	38	39	40
Production Rate, mmgpd	20	20	20	20	20	20	54.5	54.5	54.5	54.5
Power Cost, mills/kwhr	10	10	10	10	10	10	3	3	3	3
Steam Cost, ¢/1000 lb	20	70	120	20	70	120	20	70	120	20
Brine Heater Temperature, °F	250	250	250	350	350	350	250	250	250	350
Run No.	41	42	43	44	45	46	47	48	49	50
Production Rate, mmgpd	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5
Power Cost, mills/kwhr	3	3	6.5	6.5	6.5	6.5	6.5	6.5	10	10
Steam Cost, ¢/1000 lb	70	120	20	70	120	20	70	120	20	70
Brine Heater Temperature, °F	350	350	250	250	250	350	350	350	250	250
Run No.	51	52	53	54						
Production Rate, mmgpd	54.5	54.5	54.5	54.5						
Power Cost, mills/kwhr	10	10	10	10						
Steam Cost, ¢/1000 lb	120	20	70	120						
Brine Heater Temperature, °F	250	350	350	350						

PARAMETRIC COST STUDIES

TABLE 10

INPUT DATA - CONSTANT FOR ALL RUNS

ITEM	CARD NO.	COLUMN	INPUT
Problem Identification	1	1-72	Burns and Roe - Saline Water Conversion - Parametric Study
Production Rate, lb/hr	2	1-10	
Brine Heater Temp., °F		11-20	
Sea Water Temp., °F		21-30	65.0
Concentration Ratio		31-40	1.7
Recycle Ratio		41-50	6.5
Initial TTD, °F		51-60	4.0
Steam Pressure, psia		61-70	
Initial No. of Stages		71-72	30
Condenser Tube O.D., in.	3	1-10	1.0
Condenser Tube thickness, in.		11-20	0.049
Condenser Tube length, ft		21-30	
Brine Heater Tube O.D., in		31-40	1.0
Brine Heater Tube O.D., thickness, in.		41-50	0.049
Recycle Brine Velocity, ft / sec		51-60	7.0
Recycle Brine Flow, ft^3/sec	4	1-10	5.0
Cold Fouling Factor, hr-ft^2-°F/Btu		11-20	0.0005
Hot Fouling Factor, hr-ft^2-°F/Btu		21-30	0.0010
ΔP Headers, ft of brine		31-40	4.0
Tubes/Bundle vertically		41-45	16
Minimum TTD, °F	5	1-10	2.0
Maximum TTD, °F		11-20	7.0
Initial Adjustment Increment, °F		21-30	0.5
Error Limit on Optimization		31-40	
Minimum No. of Stages		41-45	10
Maximum No. of Stages		46-50	60
Initial Adjustment No. of Stages		51-55	5
Run No.	6	1-9	
Steam Cost, $/1000 lb		10-18	
Power Cost, $/kwhr		19-27	
Condenser Surface Cost, $/ft^2		28-36	
Brine Heater Surface Cost $/ft^2		37-45	
Concrete Vessel Cost, $/stage		46-54	
Pump Cost $/brake hp		55-63	85.00
Steel Vessel Cost, $/stage		64-72	
Identification for Economic Summary	7	1-72	Burns and Roe - Saline Water Conversion - Parametric Study

TABLE 11

PARAMETRIC COST STUDIES

VARIABLE INPUT DATA

Run No.	1-54	
Steam Cost, \$/1000 lb	.20, .70, and 1.20	
Power Cost, \$/kwhr	.0030, .0065 and .0100	
Brine Heater Temp., °F	250	350
Steam Pressure, psia	45	160

	1 MMGPD	20 MMGPD	54.5 MMGPD
Production Rate, lb/hr	347,260	6,945,200	18,925,700
Condenser Tube Length, ft	10	20	30
Error Limit on Optimization	.80	.09	.06
Condenser Surface Cost, \$/ft^2	6.50	3.10	2.35
Brine Heater Surface Cost, \$/ft^2	12.20	5.80	4.40
Concrete Vessel Cost, \$/stage	15,000	86,000	190,000
Steel Vessel Cost, \$/stage	56,000	320,000	720,000

TABLE 12

PARAMETRIC COST STUDIES

SUMMARY OF ECONOMIC DATA FOR OPTIMUM WATER PLANTS FROM REPRESENTATIVE COMPUTER RUNS

Computer Run No.	No. of Stages	TTD °F	Structure Cost MM $	Total Capital Cost MM $	Steam Cost 30 years MM $	Power Cost 30 years MM $	Capital Cost, 30 years MM $	Total Cost 30 years MM $
7	21	6.1	0.12	0.65	2.0	0.10	1.4	3.52
8	37	3.2	0.22	1.16	4.2	0.15	2.6	6.88
9	50	2.6	0.34	1.50	5.8	0.24	3.4	9.62
10	22	7.0	0.46	0.85	1.8	0.05	1.9	3.74
11	31	3.9	0.64	1.27	4.4	0.05	2.9	7.26
12	44	3.0	0.92	1.76	5.8	0.07	4.0	9.75
25	36	4.8	1.26	8.68	28.1	1.41	19.1	48.59
27	60	2.1	2.33	18.29	101 4	1.32	40.4	143.05
28	30	6.0	3.62	8.79	29.2	0.40	19.3	48.97
29	60	3.1	7.25	17.17	59.0	0.81	37.9	97.61
43	49	6.0	3.96	23.32	76.2	1.27	51.2	128.80
44	60	3.5	4.73	38.39	194.8	0.71	84.5	280.11
45	60	3.0	4.73	44.59	315.1	0.50	98.3	413.89
47	60	4.0	15.33	43.58	176.9	0.25	96.0	273.26
48	60	3.5	15.33	48.07	290.5	0.19	106.0	396.65

for the optimum plant in representative computer runs.

Since capital costs were found to be essentially independent of power cost in the range considered, Table 12 summarizes the output for a power cost of 6.5 mills/kwhr only. The results are comparable for power costs of 3 and 10 mills/kwhr. Runs 26 and 30 are omitted from the tabulation since convergence was not obtained because the number of stages in the optimum plant for these runs exceeded the maximum as specified in the input data (Runs 24, 32 and 36 at other power costs likewise failed to converge). Run 46 is also omitted because the results were invalid due to an error in preparation of data cards.

Subsequent to the computer runs, it was found that overly high cost estimates were used for the concrete structures. Therefore, for all cases, the cost of concrete structures as given by the computer output was reduced by an amount which is a function of the production rate. Figure 39 shows the concrete vessel cost as a function of production rate as used in the computer runs and as corrected. It has been assumed that correcting the structure cost subsequent to the computer runs does not affect the optimum number of stages or terminal temperature difference in any run.

The values in Table 12 in the column headed "Total Capital Cost" are corrected costs as discussed above and, therefore, differ from the actual computer output. This correction is also incorporated in the data in the columns listing 30-year capital cost and 30-year total cost.

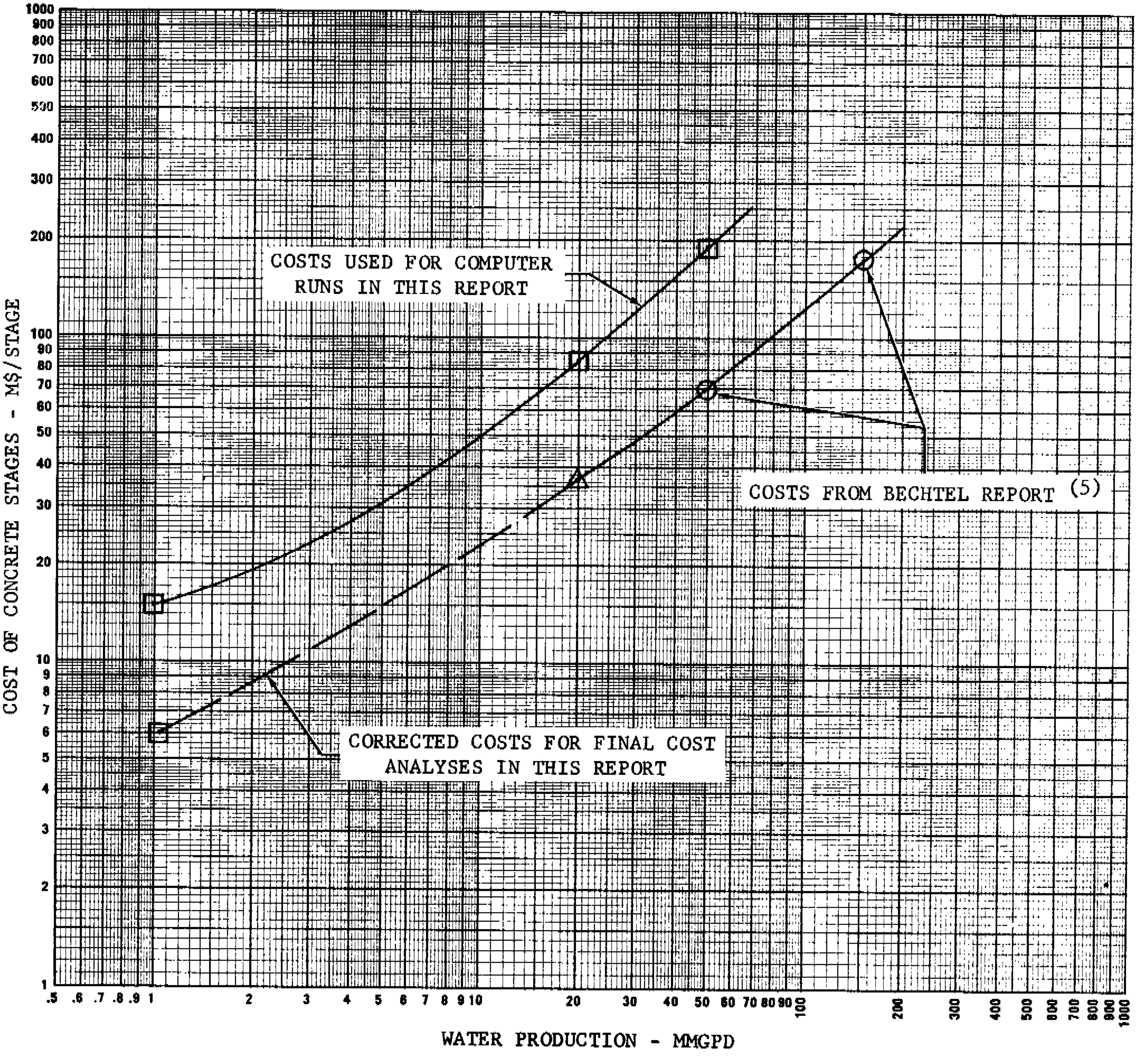
4. Capital Cost Curves

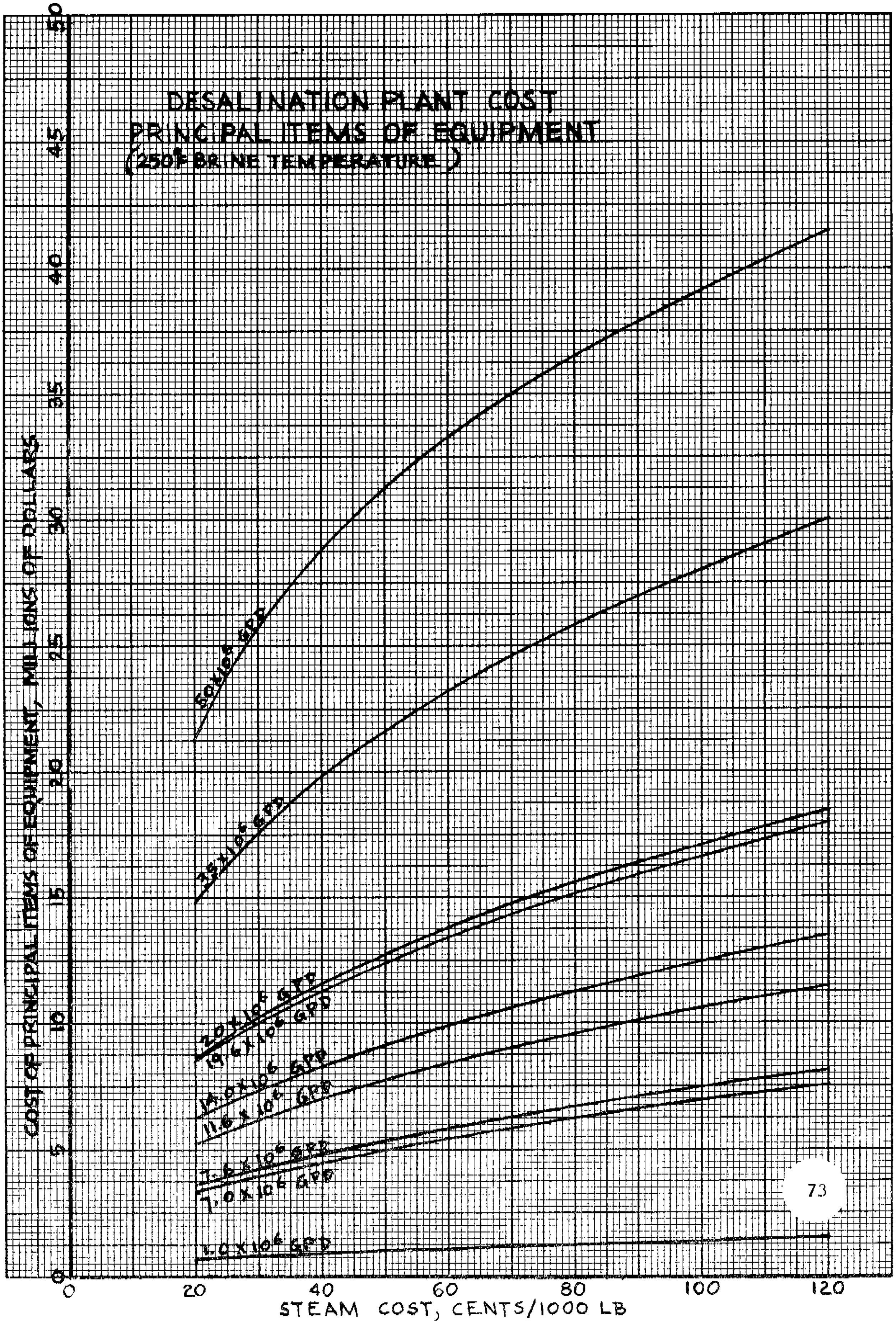
The corrected costs of principal items of equipment are plotted as functions of production rate in Figures 40 and 41. Data for these curves are taken from Table 12, under the column headed "Total Capital Cost."

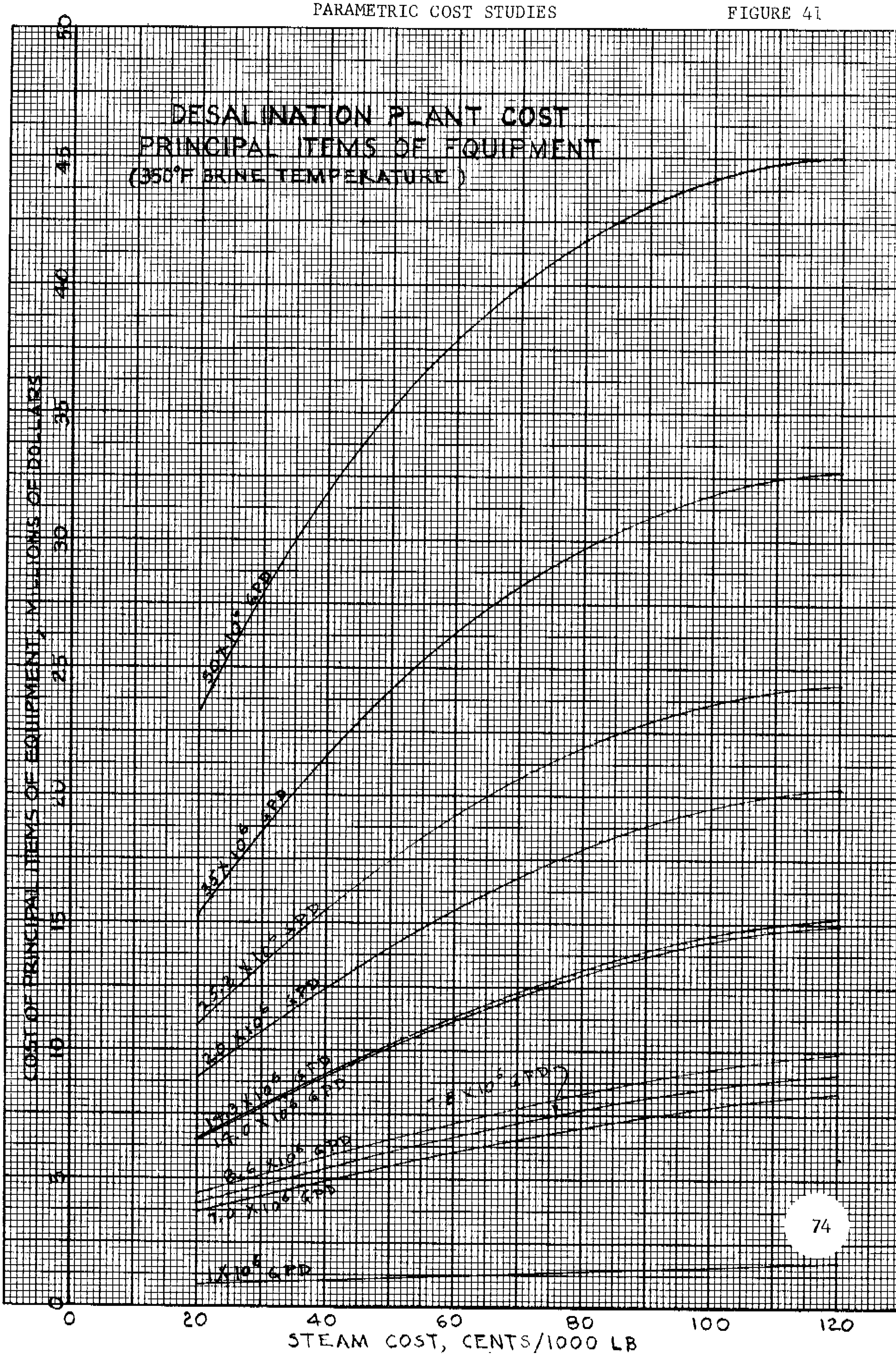
Separate plots have been made for 250° F and 350° F brine heater temperatures, with steam cost as a parameter. No appreciable variation in cost was found at the three power costs considered; therefore, the plots represent average values over the range of 3-10/mills/kwhr.

PARAMETRIC COST STUDIES

COST OF CONCRETE STAGES
FLASH EVAPORATION DESALINATION PLANT




DESALINATION PLANT COST
PRINCIPAL ITEMS OF EQUIPMENT
(250°F BRINE TEMPERATURE)
50x10⁶ GPD
35x10⁶ GPD
20x10⁶ GPD
19.6x10⁶ GPD
14.0x10⁶ GPD
11.6x10⁶ GPD
7.6x10⁶ GPD
7.0x10⁶ GPD
1.0x10⁶ GPD
COST OF PRINCIPAL ITEMS OF EQUIPMENT, MILLIONS OF DOLLARS
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
STEAM COST, CENTS/1000 LB


DESALINATION PLANT COST
PRINCIPAL ITEMS OF EQUIPMENT
(350°F BRINE TEMPERATURE)
COST OF PRINCIPAL ITEMS OF EQUIPMENT, MILLIONS OF DOLLARS
STEAM COST, CENTS/1000 LB
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
50 X 10⁶ GPD
35 X 10⁶ GPD
25.2 X 10⁶ GPD
20 X 10⁶ GPD
14.5 X 10⁶ GPD
12.0 X 10⁶ GPD
7.5 X 10⁶ GPD
8.6 X 10⁶ GPD
5.0 X 10⁶ GPD
1 X 10⁶ GPD

The capital costs given in the computer output are variable capital costs and do not include some fixed costs which are constant for all runs. The curves plotted from the computer output have been used to determine actual capital costs, both variable and fixed, as discussed elsewhere in this report.

5. Performance Ratio Curves

Performance ratio for the optimum designs has been plotted as a function of production rate, with steam cost as a parameter. These plots appear as Figures 42 through 44, for 250° F and 350° F brine heater temperature, with separate curves for power costs of 3, 6.5 and 10 mills/kwhr.

The computer program assumes saturated steam entering the brine heaters with saturated liquid leaving, and the performance ratio is based upon these conditions. If wet steam is fed to the brine heaters the actual performance ratio will be decreased, since more steam will be required to supply the same quantity of heat. However, aside from performance ratio, the steam quality will not affect the desalination plant.

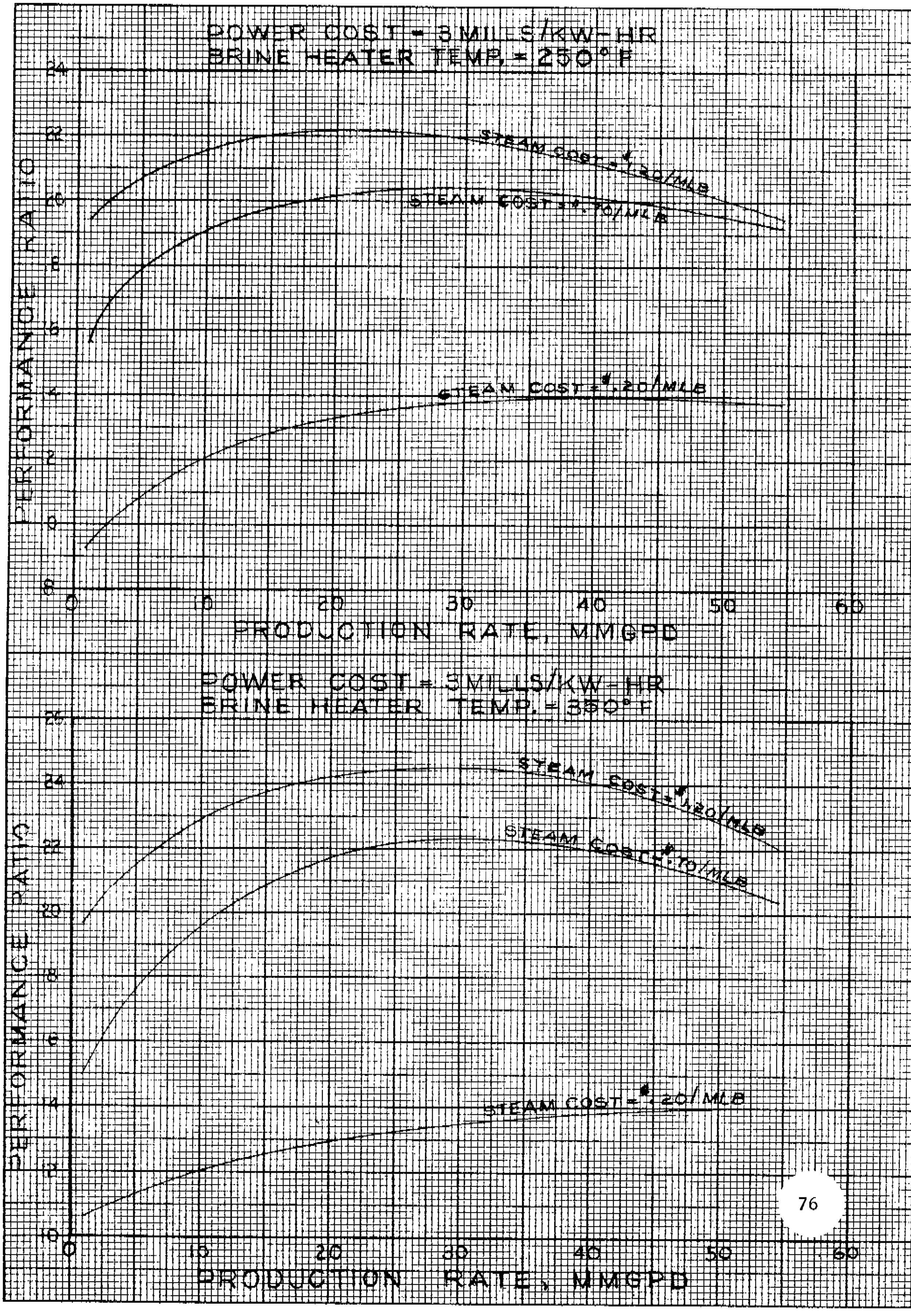
6. Cross Plots

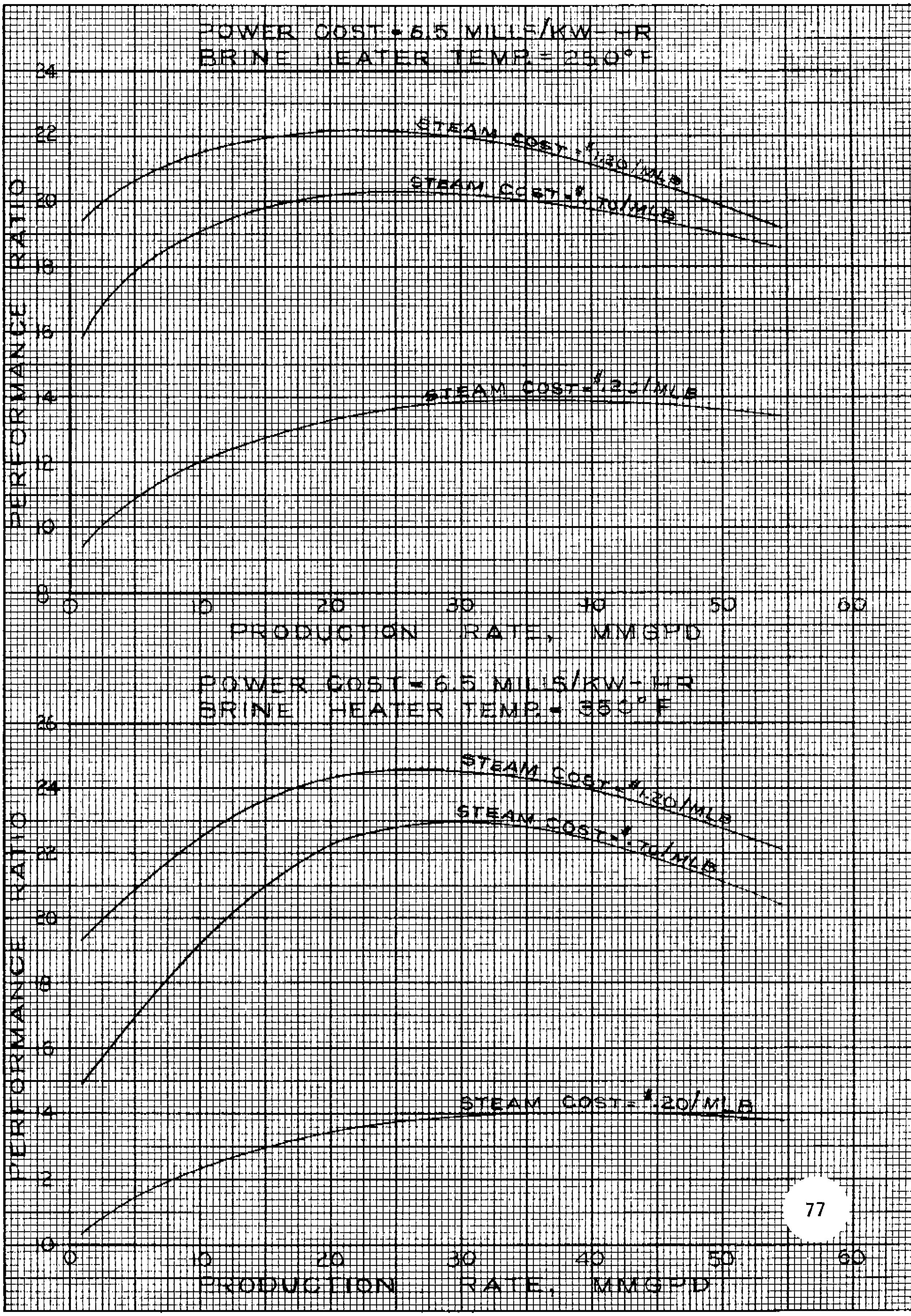
The performance ratio curves plotted as a function of production rate have been used to prepare cross plots of these variables as a function of steam cost. Figures 45 through 52 give the performance ratio as a function of steam cost with separate curves for 250° F and 350° F brine heater temperature.

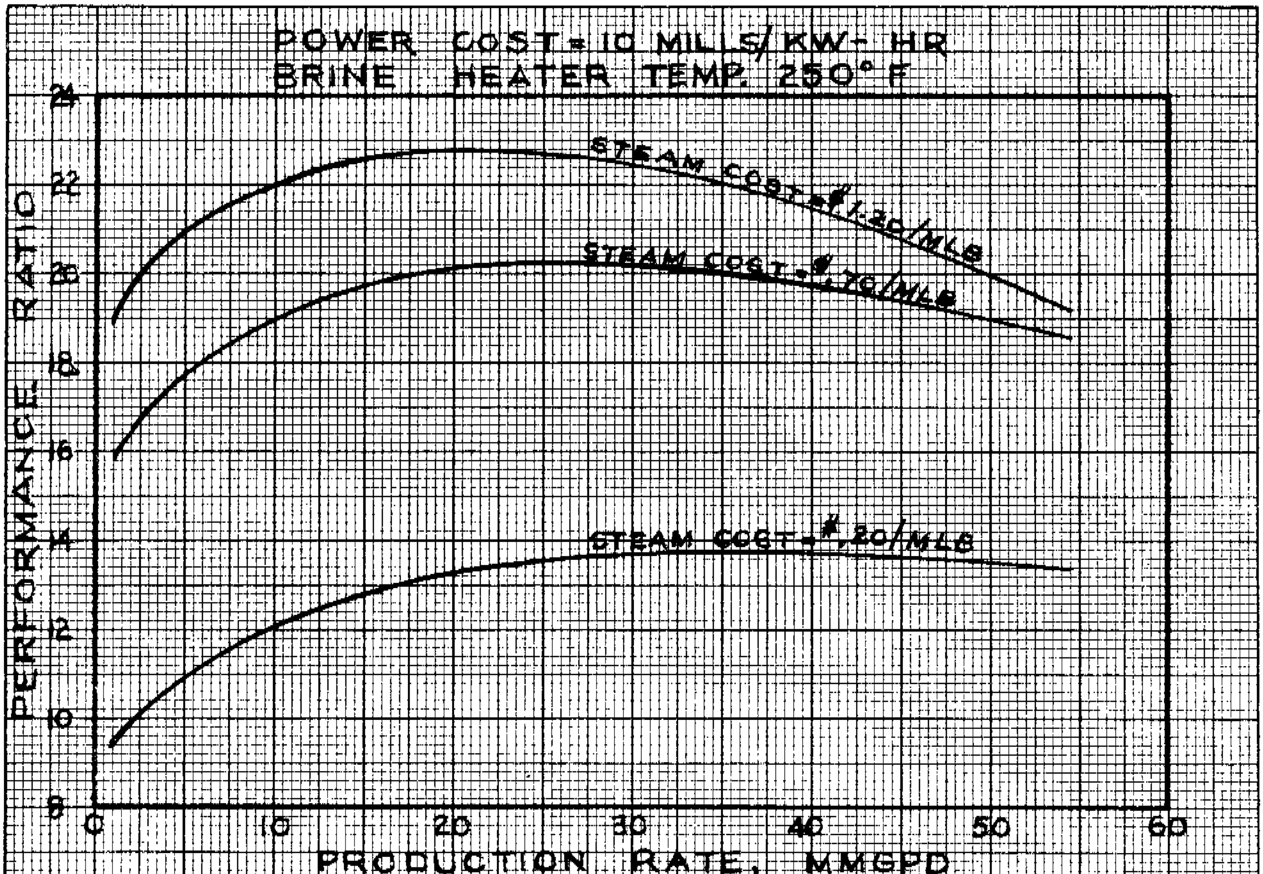
Since the cost of power affected the performance ratio to some extent, the curves for performance ratio are plotted with power cost as a parameter.

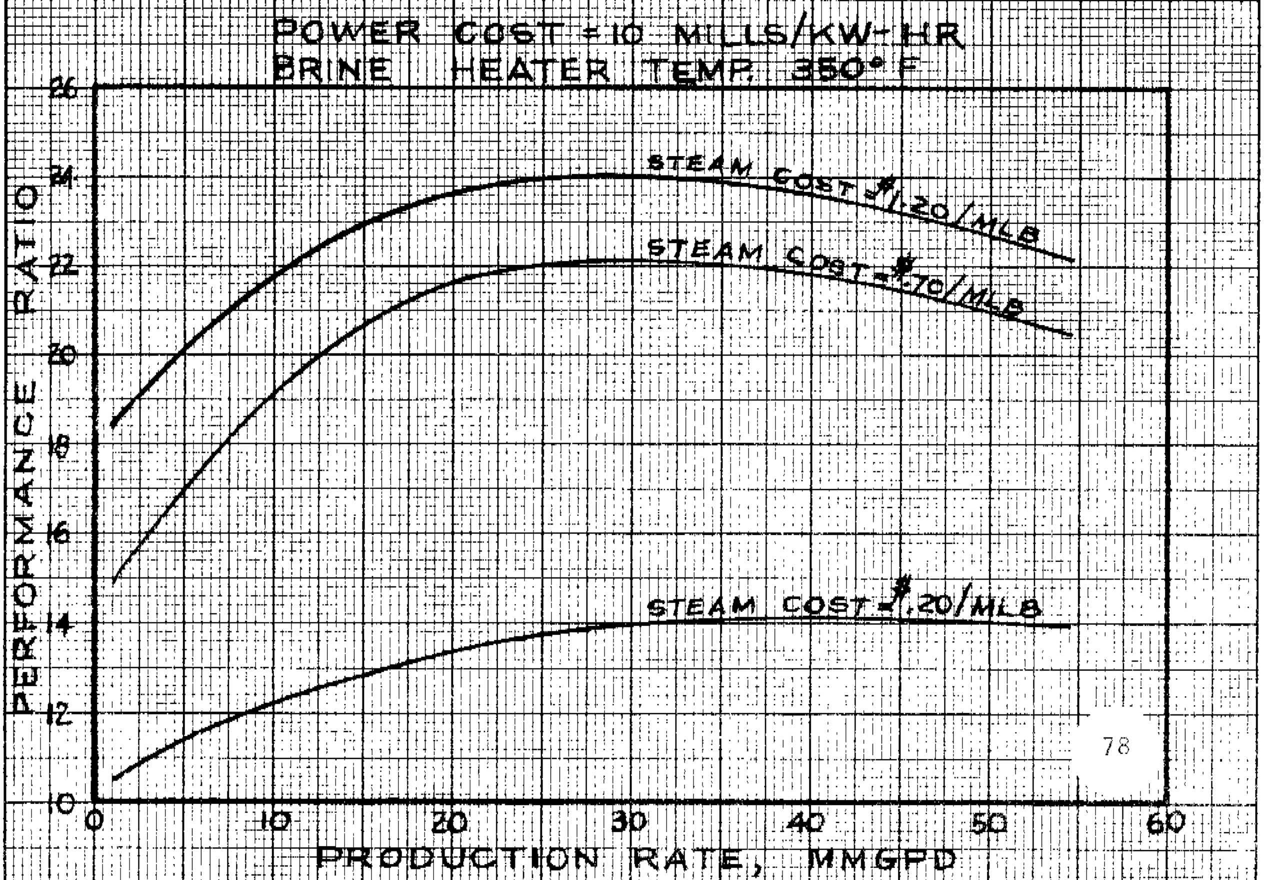
G. Unit Cost Calculations

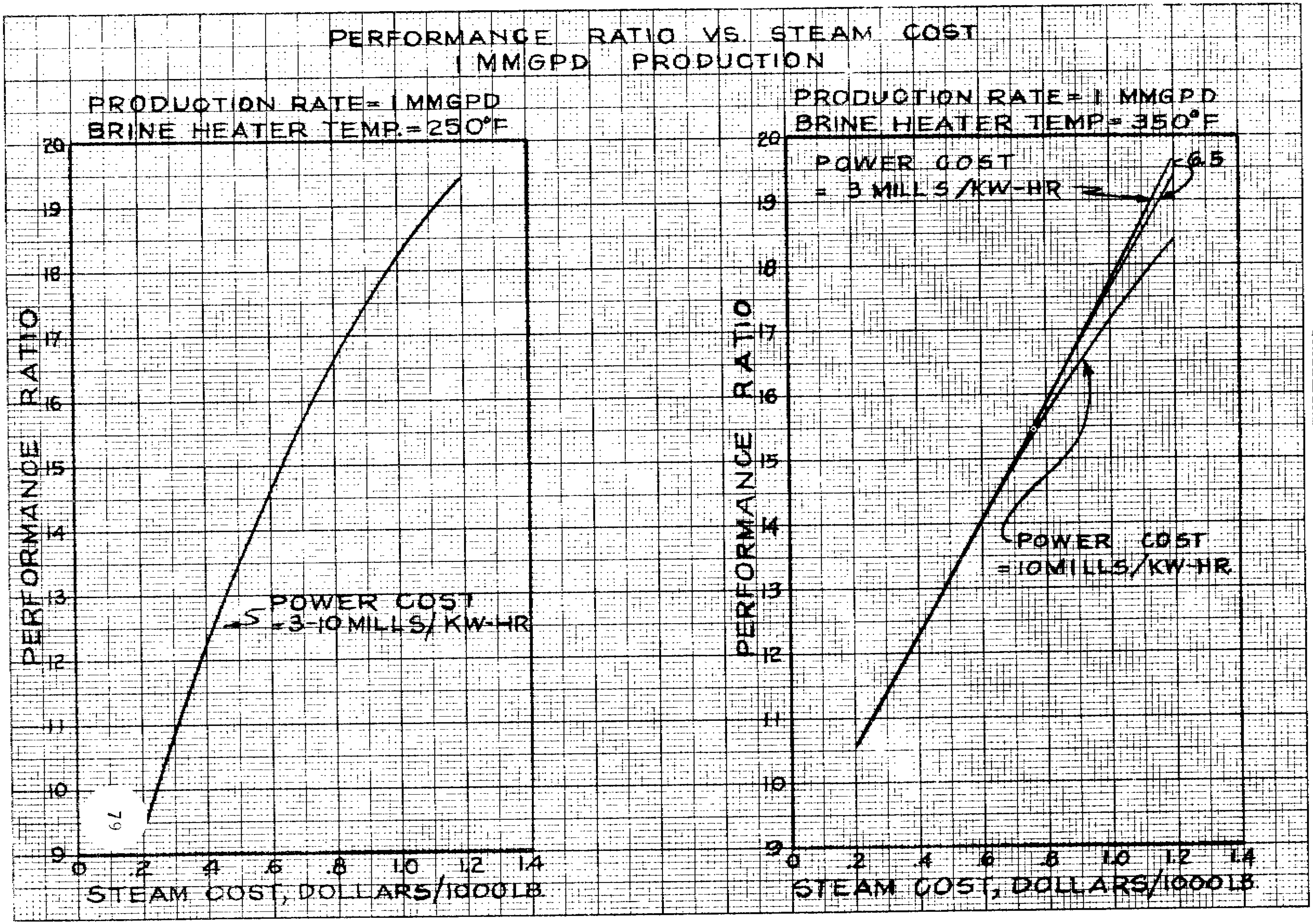
Unit costs of steam, electricity and water were determined for each optimum set of design parameters selected by the computer program. These costs have been developed generally by following standard procedures set up by the Atomic Energy Commission for power plant evaluation and by the


POWER COST = 3MILLS/KW-HR
BRINE HEATER TEMP. = 250°F
STEAM COST = $1.20/MLB
STEAM COST = $.70/MLB
STEAM COST = $.20/MLB
PERFORMANCE RATIO
24
22
20
18
16
14
12
10
8
0
10
20
30
40
50
60
PRODUCTION RATE, MMGPD
POWER COST = 5MILLS/KW-HR
BRINE HEATER TEMP. = 350°F
STEAM COST = $1.20/MLB
STEAM COST = $.70/MLB
STEAM COST = $.20/MLB
PERFORMANCE RATIO
26
24
22
20
18
16
14
12
10
0
10
20
30
40
50
60
PRODUCTION RATE, MMGPD


POWER COST = 6.5 MILLS/KW-HR
BRINE HEATER TEMP. = 250°F
STEAM COST = $1.20/MLB
STEAM COST = $.70/MLB
STEAM COST = $.20/MLB
PERFORMANCE RATIO
PRODUCTION RATE, MMGPD
POWER COST = 6.5 MILLS/KW-HR
BRINE HEATER TEMP. = 350°F
STEAM COST = $1.20/MLB
STEAM COST = $.70/MLB
STEAM COST = $.20/MLB
PERFORMANCE RATIO
PRODUCTION RATE, MMGPD

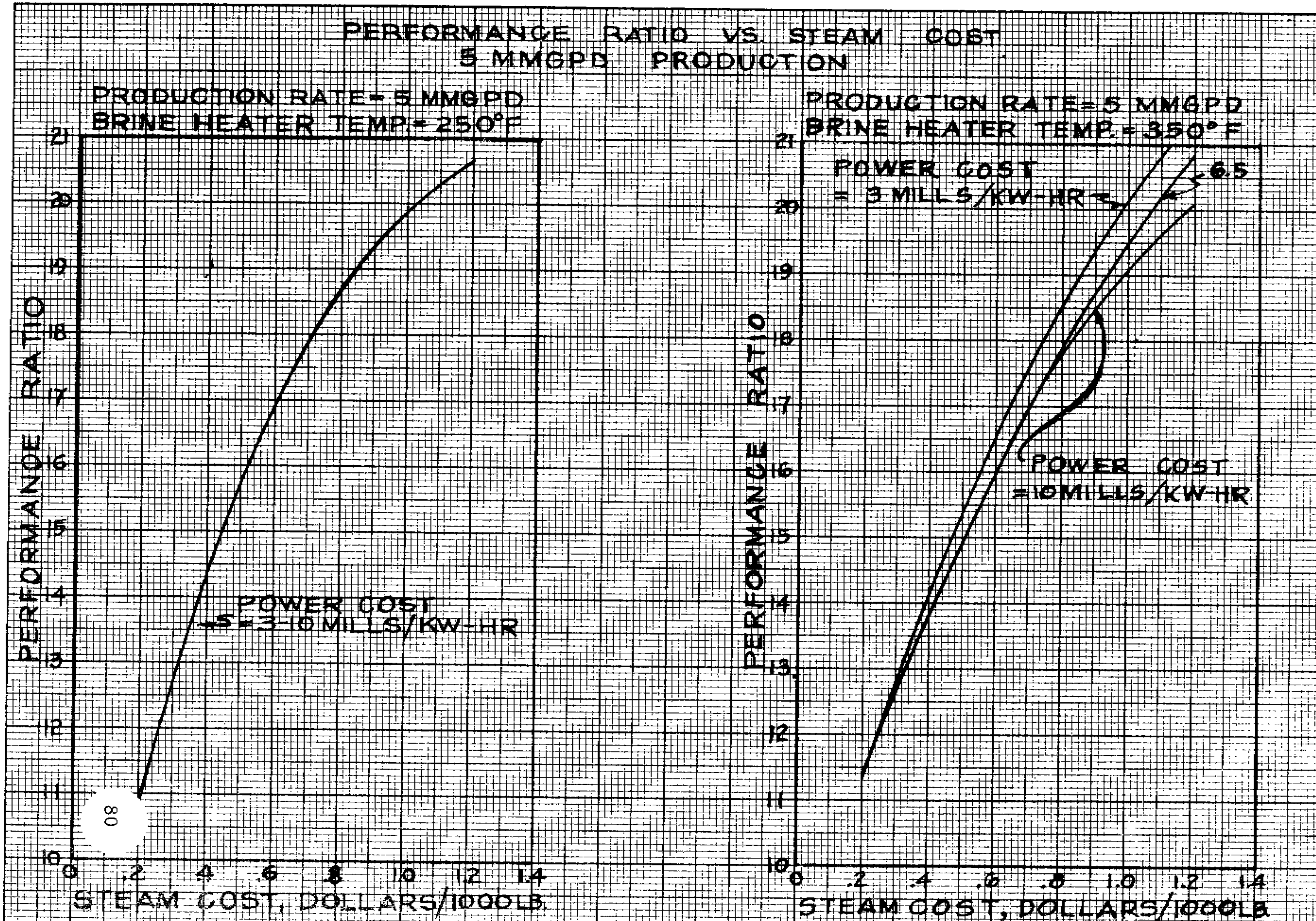

POWER COST = 10 MILLS/KW-HR
BRINE HEATER TEMP. 250° F
PERFORMANCE RATIO
PRODUCTION RATE, MMGPD
STEAM COST = $1.20/MLB
STEAM COST = $.70/MLB
STEAM COST = $.20/MLB
24
22
20
18
16
14
12
10
8
0
10
20
30
40
50
60


POWER COST = 10 MILLS/KW-HR
BRINE HEATER TEMP. 350° F
PERFORMANCE RATIO
PRODUCTION RATE, MMGPD
STEAM COST = $1.20/MLB
STEAM COST = $.70/MLB
STEAM COST = $.20/MLB
26
24
22
20
18
16
14
12
10
0
10
20
30
40
50
60



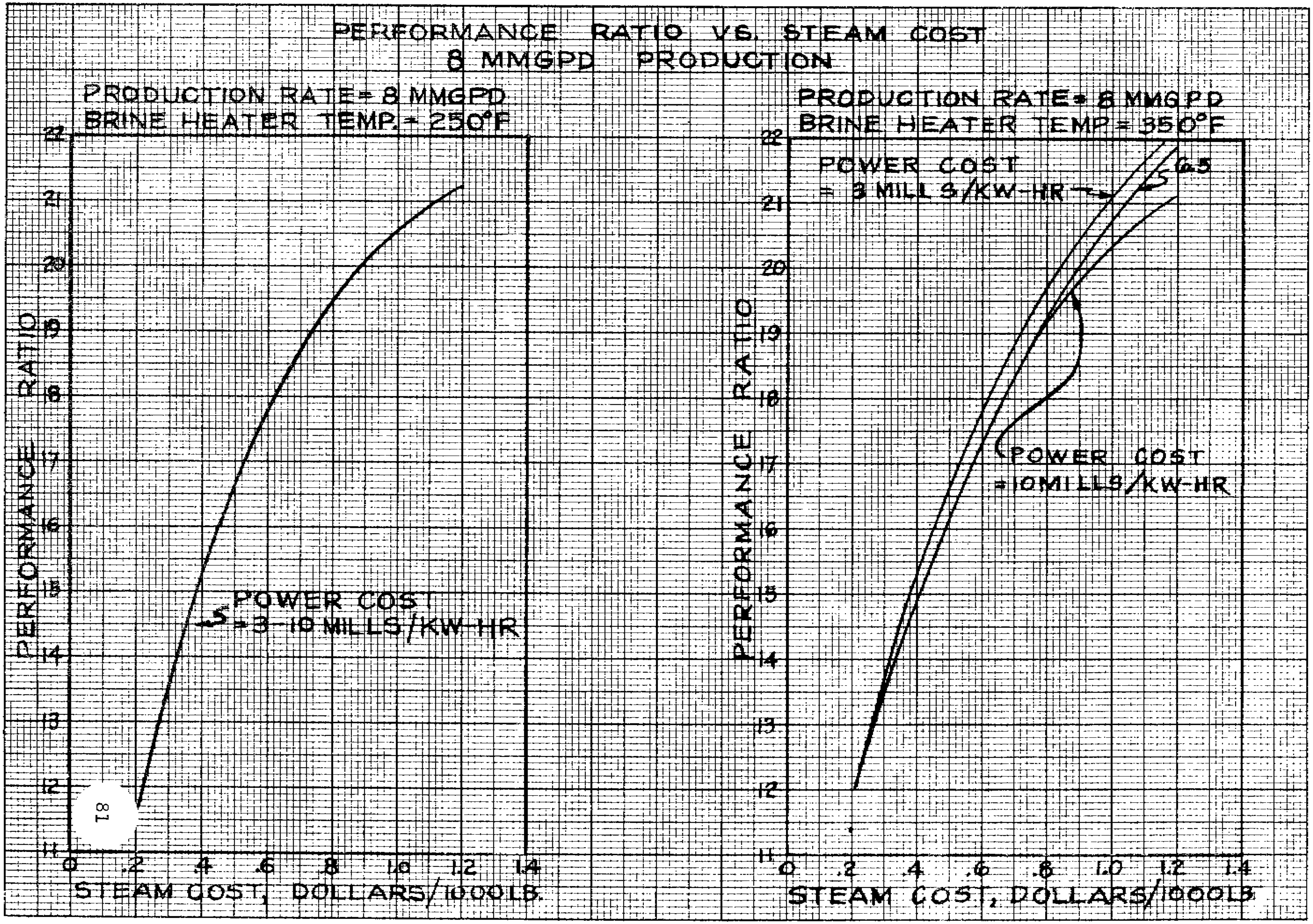
PERFORMANCE RATIO VS. STEAM COST
1 MMGPD PRODUCTION
PRODUCTION RATE = 1 MMGPD
BRINE HEATER TEMP. = 250°F
POWER COST = 3-10 MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000 LB.
PRODUCTION RATE = 1 MMGPD
BRINE HEATER TEMP = 350°F
POWER COST = 3 MILLS/KW-HR
6.5
POWER COST = 10 MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000 LB.

FIGURE 45



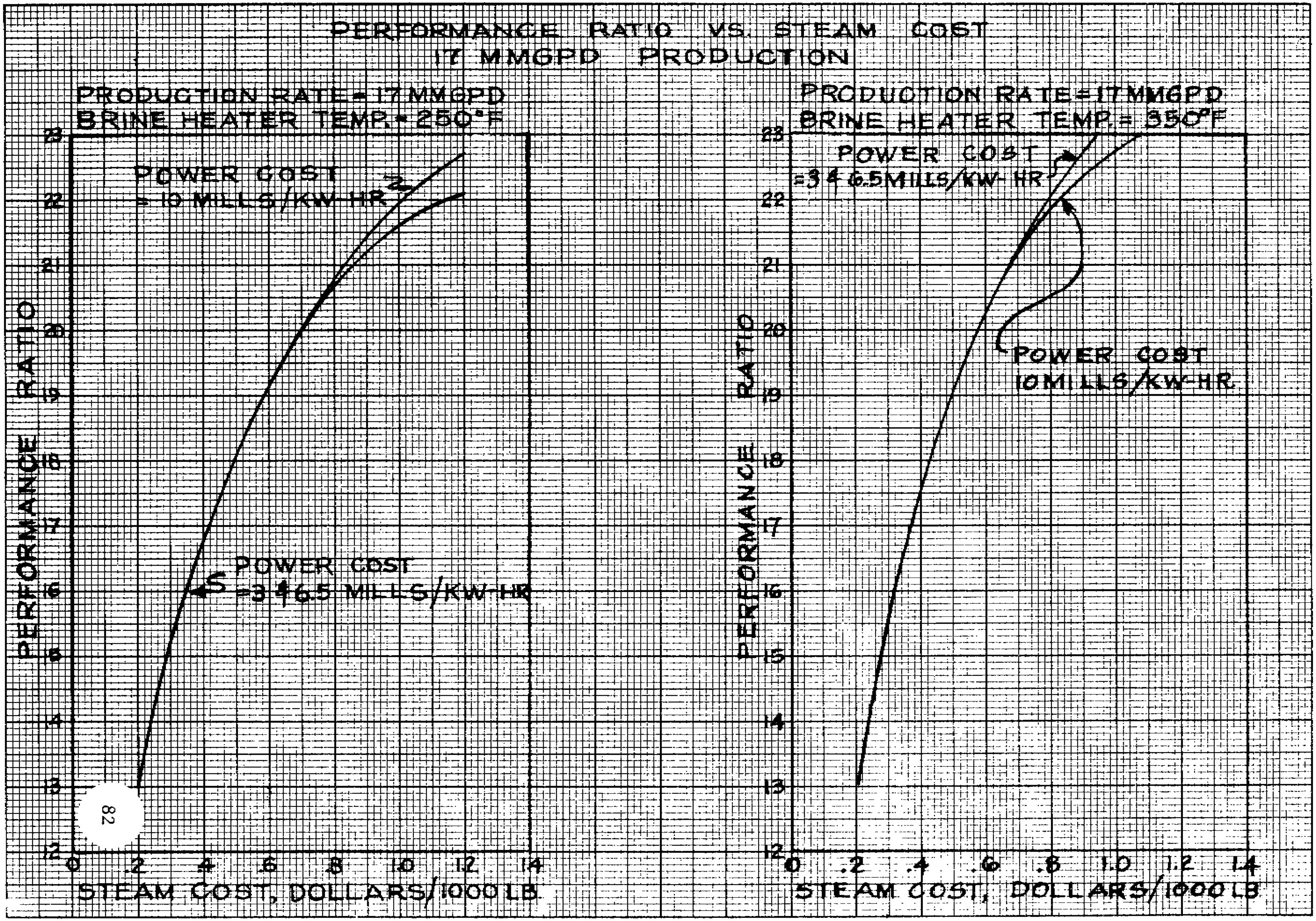
PARAMETRIC COST STUDIES

FIGURE 46



PARAMETRIC COST STUDIES

FIGURE 47



PARAMETRIC COST STUDIES

FIGURE 48

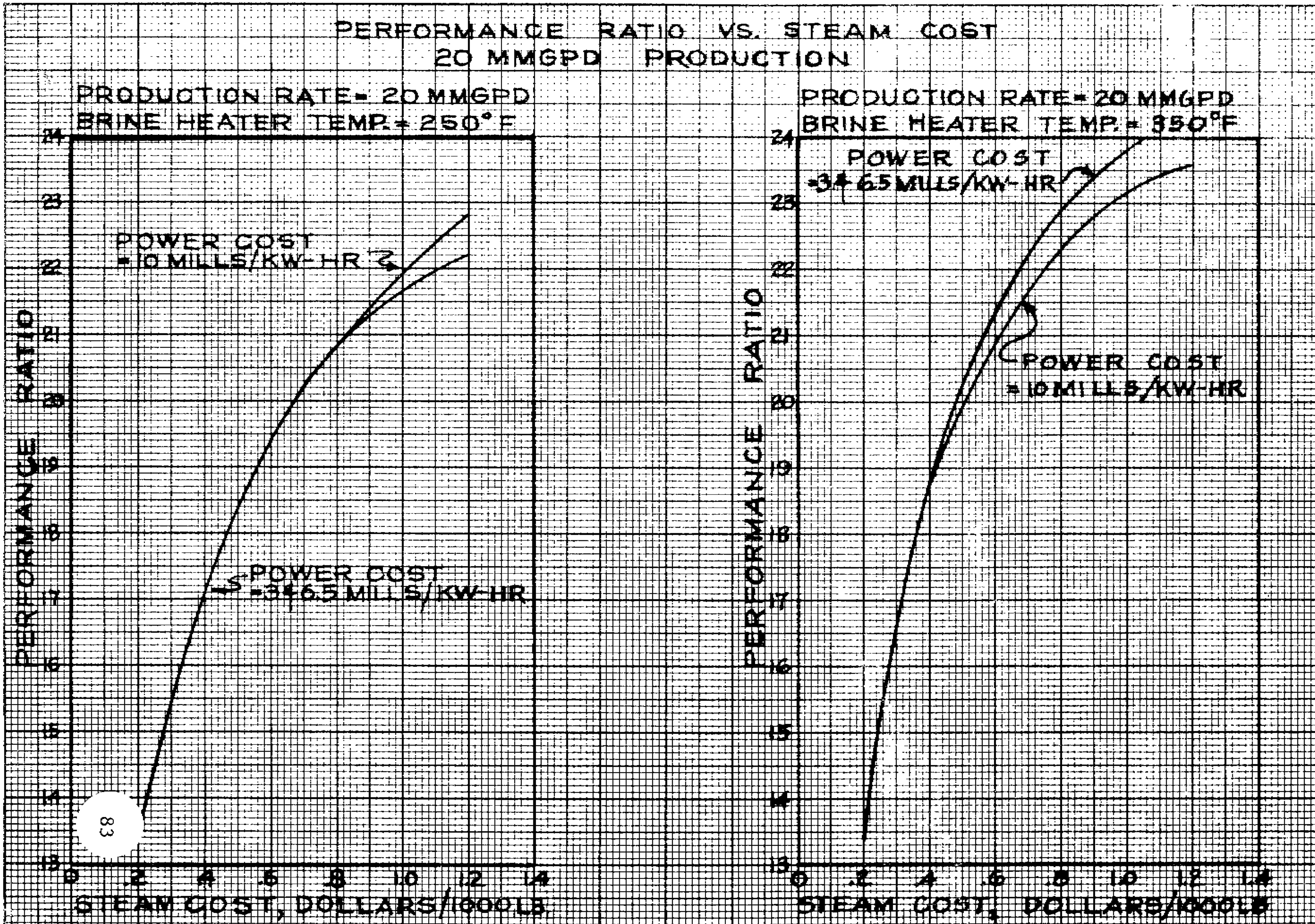

PERFORMANCE RATIO VS. STEAM COST
20 MMGPD PRODUCTION
PRODUCTION RATE = 20 MMGPD
BRINE HEATER TEMP. = 250°F
POWER COST
= 10 MILLS/KW-HR
POWER COST
= 3 & 6.5 MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000 LB.
PRODUCTION RATE = 20 MMGPD
BRINE HEATER TEMP. = 350°F
POWER COST
= 3 & 6.5 MILLS/KW-HR
POWER COST
= 10 MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000 LB.
13
14
15
16
17
18
19
20
21
22
23
24
0
.2
.4
.6
.8
1.0
1.2
1.4

FIGURE 49

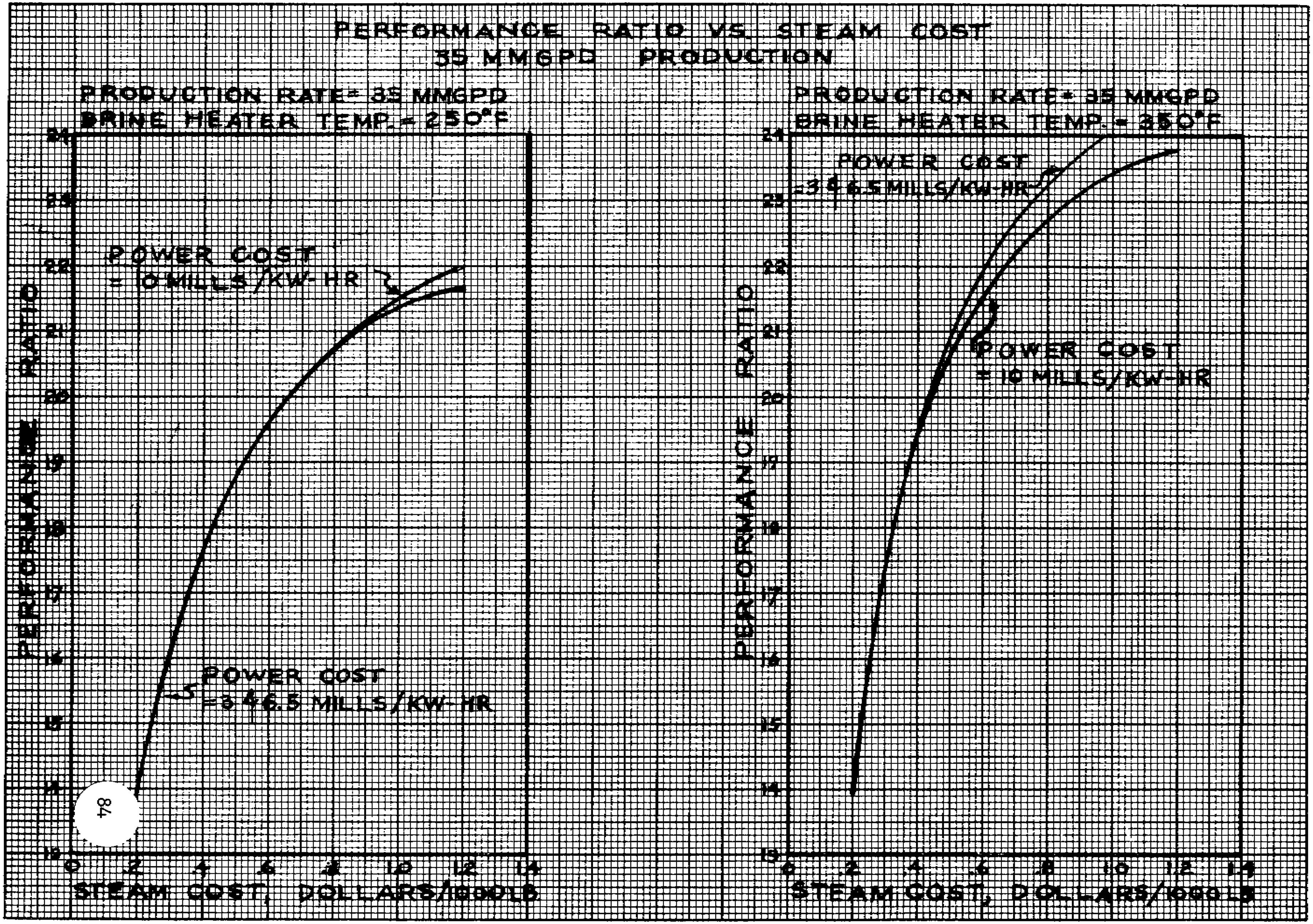

PERFORMANCE RATIO VS. STEAM COST
35 MMGPD PRODUCTION
PRODUCTION RATE = 35 MMGPD
BRINE HEATER TEMP. = 250°F
POWER COST = 10 MILLS/KW-HR
POWER COST = 3 & 6.5 MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000 LB
PRODUCTION RATE = 35 MMGPD
BRINE HEATER TEMP. = 350°F
POWER COST = 3 & 6.5 MILLS/KW-HR
POWER COST = 10 MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000 LB

FIGURE 50

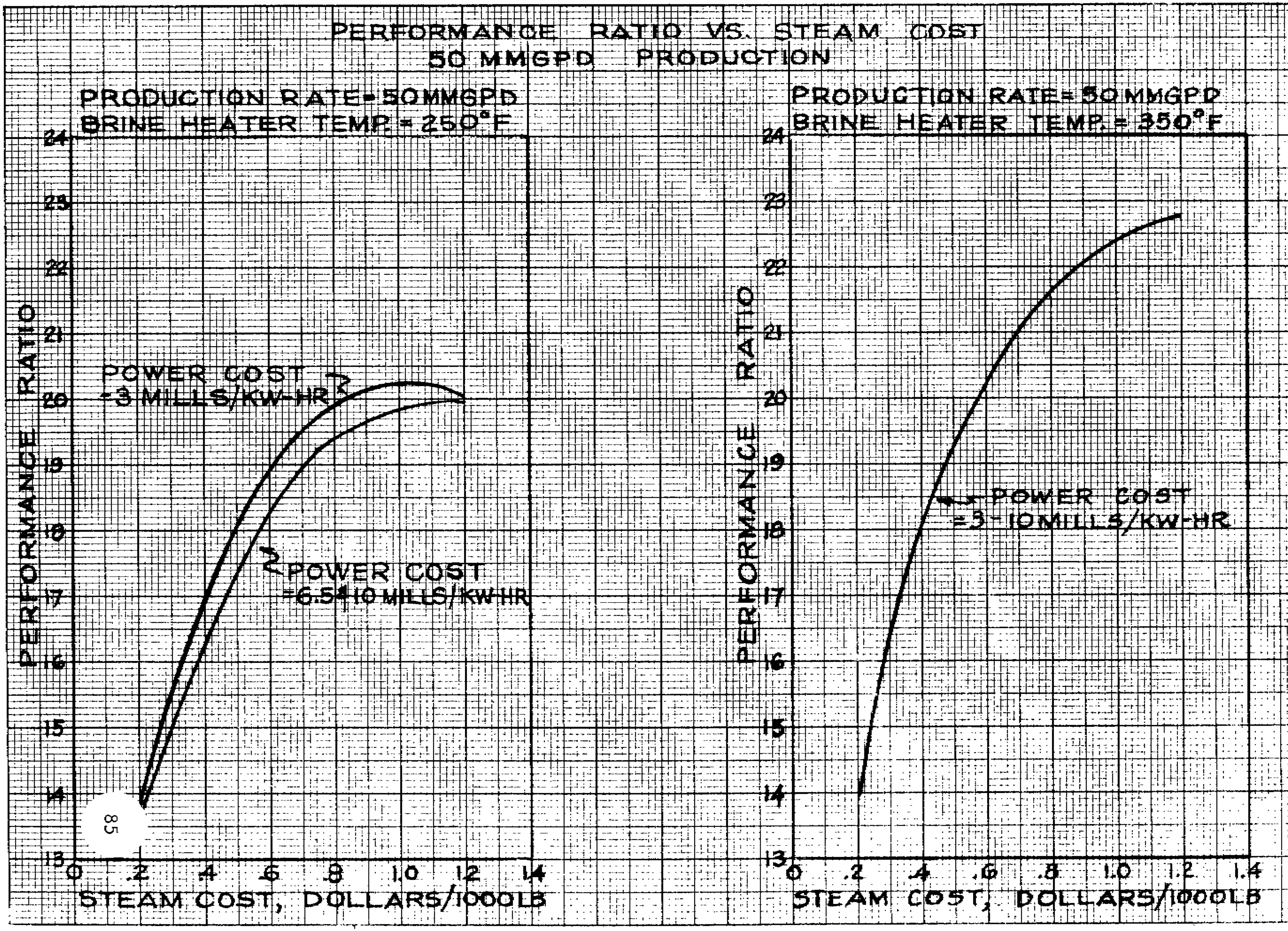

PERFORMANCE RATIO VS. STEAM COST
50 MMGPD PRODUCTION
PRODUCTION RATE=50MMGPD
BRINE HEATER TEMP.=250°F
POWER COST =3 MILLS/KW-HR
POWER COST =6.5-10 MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000LB
PRODUCTION RATE=50MMGPD
BRINE HEATER TEMP.=350°F
POWER COST =3-10MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000LB
13
14
15
16
17
18
19
20
21
22
23
24
0
.2
.4
.6
.8
1.0
1.2
1.4

FIGURE 51

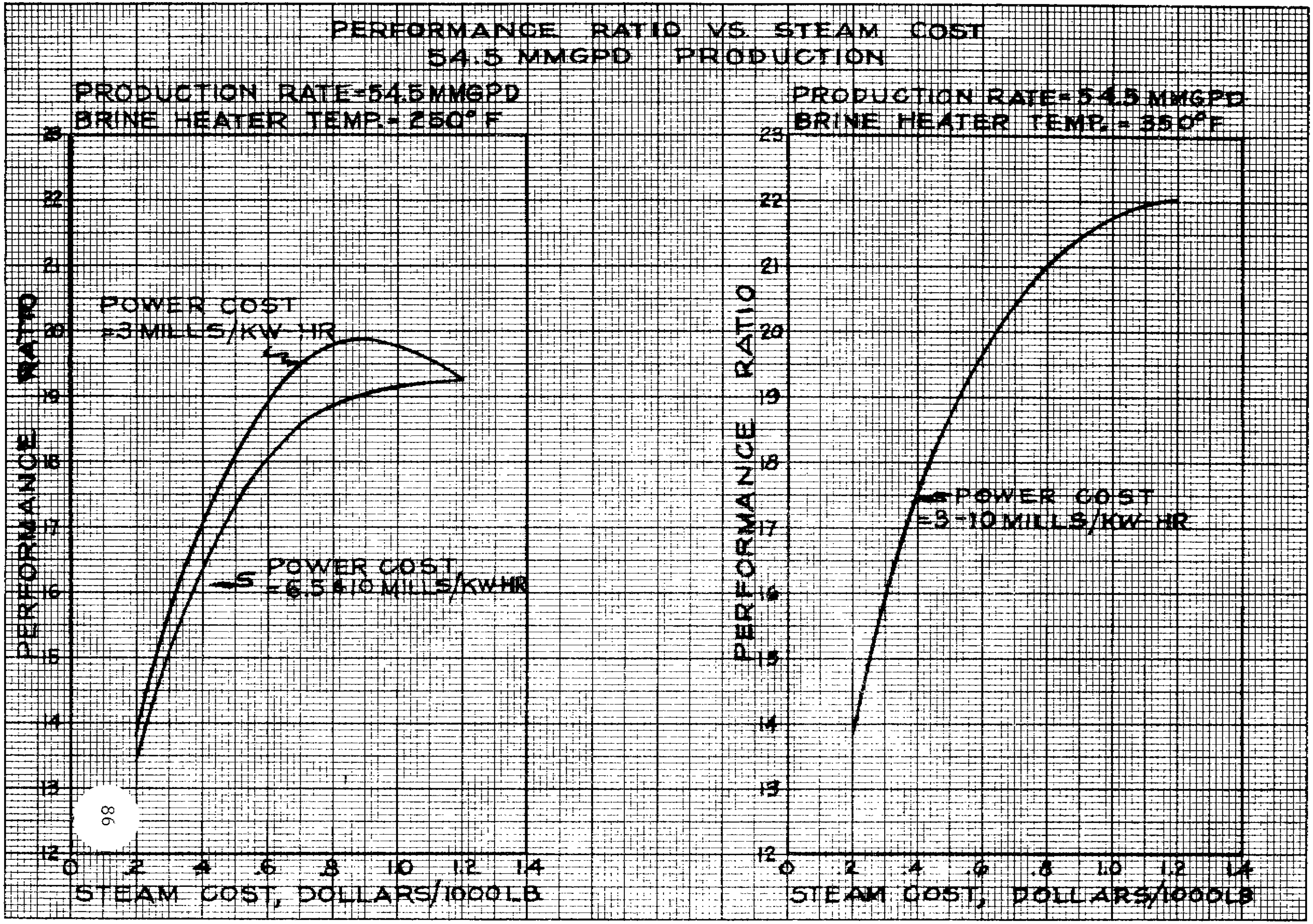

PERFORMANCE RATIO VS. STEAM COST
54.5 MMGPD PRODUCTION
PRODUCTION RATE=54.5 MMGPD
BRINE HEATER TEMP.=250° F
POWER COST =3 MILLS/KW-HR
POWER COST =6.5 ±10 MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000LB
PRODUCTION RATE=54.5 MMGPD
BRINE HEATER TEMP.=350°F
POWER COST =3-10 MILLS/KW-HR
PERFORMANCE RATIO
STEAM COST, DOLLARS/1000LB

FIGURE 52

Office of Saline Water for desalination plant studies. The standard procedures have been modified, where necessary, to place both power and desalination plants on the same basis. Deviations from the assumptions implicit in the standard procedures have also been introduced where more exact data are available for the specific cases being investigated.

The methods used for estimating steam, electricity and water costs are discussed separately below:

1. Steam Costs

a. Nuclear Steam Costs

Procedures recommended in TID-7025, "Guide to Nuclear Power Cost Evaluation," form the basis for the nuclear reactor steam cost estimates. Accordingly a plant capacity factor of 80 percent was assumed. The municipal fixed charge rates, however, were adjusted slightly to incorporate a 4 percent interest charge instead of 3.74 percent. The higher interest rate was chosen to be consistent with the 4 percent interest rate in the computer program which was used for determination of optimum desalination plant parameters.

The total fixed charge rate of 7.93 percent for depreciating items and 5.80 percent for nondepreciating items is made up as follows:

	Depreciating, %	Nondepreciating, %
Interest Charged	4.00	4.00
Depreciation (30-year sinking fund)	1.78	--
Interim Replacements	0.35	--
Property Insurance	0.40	0.40
State and Local Taxes	1.40	1.40
	7.93	5.80

The breakdown of annual and unit steam costs is shown on Table 13. Of the items tabulated, land and land rights, nuclear liability insurance, operating and maintenance, and fuel cost components have been discussed previously in Items B, C and D; the two remaining items, total capital cost and working capital, are estimated as follows:

(1) Total Capital Cost

The total capital cost includes nuclear island capitals costs, common facilities investment, and interest on investment during construction.

Nuclear island capital costs versus reactor thermal power are plotted on Figure 12 except for Cases 13 and 14. The selection of data for Figure 12 and for Cases 13 and 14 is explained in Item B.

Common facilities are items such as roads, walks, railroads, fences, service buildings and guardhouses, which serve the electric generating and water desalination plants in addition to serving the steam plant. In each case these costs were estimated by the Burns and Roe, Inc. Estimating Department, and a percentage of the cost was assigned to the steam plant in accordance with the fraction of the total use of the facility required by the steam plant.

The interest on investment during construction was calculated by assuming an annual interest rate of 4 percent on money tied up in engineering and construction expenses prior to plant startup.

(2) Working Capital

In accordance with TID-7025 working capital is assumed to be the sum of the average value of materials and supplies in inventory plus 2.7 percent of the annual operating and maintenance costs including annual fuel cost.

Materials and supplies in inventory is made up of nuclear fuel inventory, taken as 60 percent of the core fabrication cost, plus other materials and supplies, assumed to be 25 percent of the annual cost of maintenance materials and operating supplies.

Core fabrication costs, for purposes of this study, are assumed to equal $7,900 per thermal megawatt of reactor capacity for all nuclear cases covered.

b. Fossil-Fuel Steam Costs

Calculation of fossil-fuel steam costs were performed in a manner similar to that used for nuclear steam costs; however, the fixed charge rates used were 7.78 percent for depreciating items and 5.65 percent for nondepreciating items. These are 0.15 percent lower than the corresponding rates for nuclear plants; the difference is due to lower property insurance rates for fossil-fuel plants.

(1) Capital Costs

Capital cost estimates for the conventional boiler plants were developed by Burns and Roe, Inc., based on data from previous projects.

(2) Operating and Maintenance Costs

Operating and maintenance costs were based on data taken from the "Bureau of Power Technical Memorandum No. 1." These were plotted and extrapolated as shown on Figure 14.

(3) Working Capital

Working capital for fossil-fuel plants was calculated in the same way as working capital for nuclear plants except for the omission of the fuel inventory component. The fuel is assumed to be gas furnished through the supplier's pipeline. Therefore no storage facilities are included.

All cost factors are shown on Table 14.

2. Costs of Electricity

Annual and unit costs of electricity are shown on Tables 15 and 16. Procedures used for calculating these costs were based on TID-7025, "Guide to Nuclear Power Cost Evaluation." The same plant capacity factor, interest rates and fixed charge rates used for estimating steam costs were also used for estimating electrical costs. These factors were discussed in Paragraph G-1 a, above, "Nuclear Steam Costs." Where steam is supplied by a nuclear reactor, nuclear plant fixed charge rates were also applied to the turbogenerator plant. Where steam is supplied by gas-fired boilers, conventional plant fixed charge rates were used.

In the calculation of steam costs, fuel costs were considered part of the operating and maintenance cost. In the calculation of electricity cost, steam costs replace the fuel portion of the operating and maintenance costs. Since in each case at least some of the steam leaving the turbine is used to supply heat to the desalination plant, the full cost of steam from the fossil or nuclear steam generating plant is not charged to the turbogenerator. For steam passing through both turbine and desalination plants, the turbine is charged with a fraction of the generated steam cost equal to the ratio of the enthalpy extracted in the turbine to the total enthalpy extracted from the steam. Those portions of steam fed to the turbine which do not go to the desalination plant but are extracted for feedwater heating or are discharged to a condenser are charged to the turbine plant at full cost. The steam costs appearing on Tables 13 and 14 are weighted averages of the costs of steam charged at full and partial cost.

3. Cost of Water Desalination

The "Standardized Procedure for Estimating Costs of Saline Water Conversion" prepared by the Office of Saline Water was followed in modified form for the water cost calculations. Modifications were made to place the desalination costs on the same basis as steam and electrical costs, and also to achieve greater accuracy where more recent data is available.

a. Capital Investment

The breakdown of the capital investment costs for the water desalination plant is shown on Table 17. A method of estimating each item in the table is explained below:

(1) Principal Items of Equipment (PIE)

The principal items of equipment figure comes directly from the computer print-out.

(2) Erection and Assembly of Plant

The OSW standard procedure assumes erection and assembly costs to be equal to 30 percent of the cost of principal items of equipment. Table 14 on page 126 of the "1962 Saline Water Conversion Report" of the Office of Saline Water, however, presents data which indicates lower costs for erection and assembly. The 1962 Saline Water Conversion Report lists more components under principal items of equipment than does the standard procedure. If the data in the 1962 report is adjusted to the same grouping of items as the standard procedure, the erection and assembly component is seen to amount to approximately 23 percent of the principal items of equipment. Accordingly, for this study, the 23 percent figure was used.

(3) Instruments

The cost of instruments was assumed to equal 2.5 percent of the cost of principal items of equipment rather than 4 percent as recommended by the standard procedure. The 2.5 percent figure is based on data from the 1962 Saline Water Conversion Report after adjustment to correspond to the standard procedure grouping of principal items of equipment.

(4) Raw Water Supply

The investment required for raw water supply was estimated by Burns and Roe, Inc. For the cases in which cooling water is required by the turbogenerator plant as well as by the desalination plant, the investment costs were apportioned on the basis of the percentage of water required by each plant.

(5) Service Facilities and Buildings

Service facilities and buildings include roads, walks, railroads, fences, service buildings, guardhouses and miscellaneous other equipment and facilities. These items serve the steam and electrical plants in addition to the desalination plant. In each case, the total cost was estimated by Burns and Roe, Inc., and a percentage of the cost was assigned to the desalination plant in accordance with the fraction of the total use of the item required by the desalination plant.

(6) Contingencies

In accordance with the OSW standard procedure, contingencies were assumed to equal 10 percent of the total of all the above items.

(7) Engineering

Engineering was assumed to amount to 10 percent of the cost of all the above items. This is in agreement with the OSW standard procedure.

(8) Interest on Investment during Construction

The OSW procedure was again followed in estimating the interest on investment during construction. This amounts to 4 percent of all the above items.

(9) Site

We have made no separate estimate of site costs for the desalination plant. In most cases, the desalination plant can be constructed within the nuclear exclusion area and so the land costs are all borne by the nuclear plant. In the fossil-fuel cases, site costs are included as part of the service facilities and buildings item.

b. Operating Costs

The desalination plant operating cost breakdown, as well as the other contributors to the unit costs, are shown on Table 18. The OSW "Standard Procedure for Estimating Costs of Saline Water Conversion" was modified to achieve consistency with the assumptions and criteria used for steam and water estimates. Each item of the operating cost breakdown is discussed briefly below:

(1) Electric Power

The electric power cost estimate is discussed in Paragraph G 2.

(2) Steam Cost

Steam costs at the steam generator were estimated as described in Paragraph G 1. The cost of steam used by the turbo-generator plant was calculated by the procedure described in Paragraph G 2.

The steam cost at the desalination plant is equal to the difference between the steam cost at the generator outlet and the steam cost to the turbogenerator plant.

(3) Chemicals

The cost of chemicals was based on operating data of the Point Loma Flash Evaporation Demonstration Plant.

(4) Supplies and Maintenance Materials

In accordance with the OSW standard procedure, supplies and maintenance materials were assumed to cost 0.5 percent of the total plant investment per year. Instead of assuming 330 stream-days per year as suggested in the standard procedure, however, an 80 percent plant capacity factor equal to 292 stream-days per year was assumed. The 80 percent factor was selected to place the desalination operating cost estimates on the same basis as the steam and electricity estimates. Thus supplies and maintenance materials were taken as 0.0017 percent of the plant investment per stream-day.

(5) Operating Labor

Operating labor costs were assumed to equal 5 percent of the above operating items plus 5 percent of the amortization (discussed in Paragraph (9) below). This is in agreement with the OSW standard procedure for large capacity plants.

(6) Maintenance Labor

In accordance with the OSW standard procedure, maintenance labor was estimated to cost 0.5 percent of the total plant investment per year. Thus the cost per stream-day amounts to 0.0017 percent for 292 stream-days.

(7) Payroll Extras

Payroll extras were estimated as 15 percent of the operating and maintenance labor. This is in agreement with the OSW standard procedure.

(8) General and Administrative Overhead

Based on Burns and Roe's field experience, general and administrative overhead expenses were assumed to equal

15 percent of the operating and maintenance labor plus payroll extras. This is half the amount suggested by the standard procedure, but it is believed to be more realistic.

(9) Amortization

To be consistent with the steam and electricity cost estimates, the desalination plant investment was amortized over a 30-year period with the interest on money at 4 percent. This yielded an amortization rate of 5.78 percent per year, or 0.0198 percent per stream-day.

(10) Taxes, Insurance and Interim Replacements

As stated in Paragraph G 1,b the fixed charge rate for conventional depreciating equipment is 7.78 percent. The amortization rate for a 30-year life with money at 4 percent is equal to 5.78 percent per year. The difference between fixed charge rate and amortization rate is due to taxes, property insurance and interim replacements (see Paragraph G 1,a). This amounts to 7.78 minus 5.78 percent, equal to 2 percent per year, or 0.00685 percent per stream-day. Thus, the 2 percent annual rate for state and local taxes and property insurance given in the OSW standard procedure is seen to also provide for interim replacements. The allowance for state and local taxes is 1.65 percent, and that for property insurance is 0.35 percent.

(11) Interest on Working Capital

Working capital is assumed to equal 60 days' production cost. With interest at 4 percent per year, and 292 stream-days per year, the working capital cost per stream-day amounts to 0.00821 times the sum of all the above operating costs.

APPENDIX A-1 REFERENCES

A. CITED

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"Steam Turbines and Their Cycles," J. Kenneth Salisbury, John Wiley & Sons, 1950

"A Method for Predicting the Performance of Steam Turbine-Generators -- 16,500 Kw and Larger," R. C. Spencer, K. C. Cotton, and C. N. Cannon (ASME Paper No. 62-WA-209), General Electric Co., Schenectady, N. Y. (GER2007)

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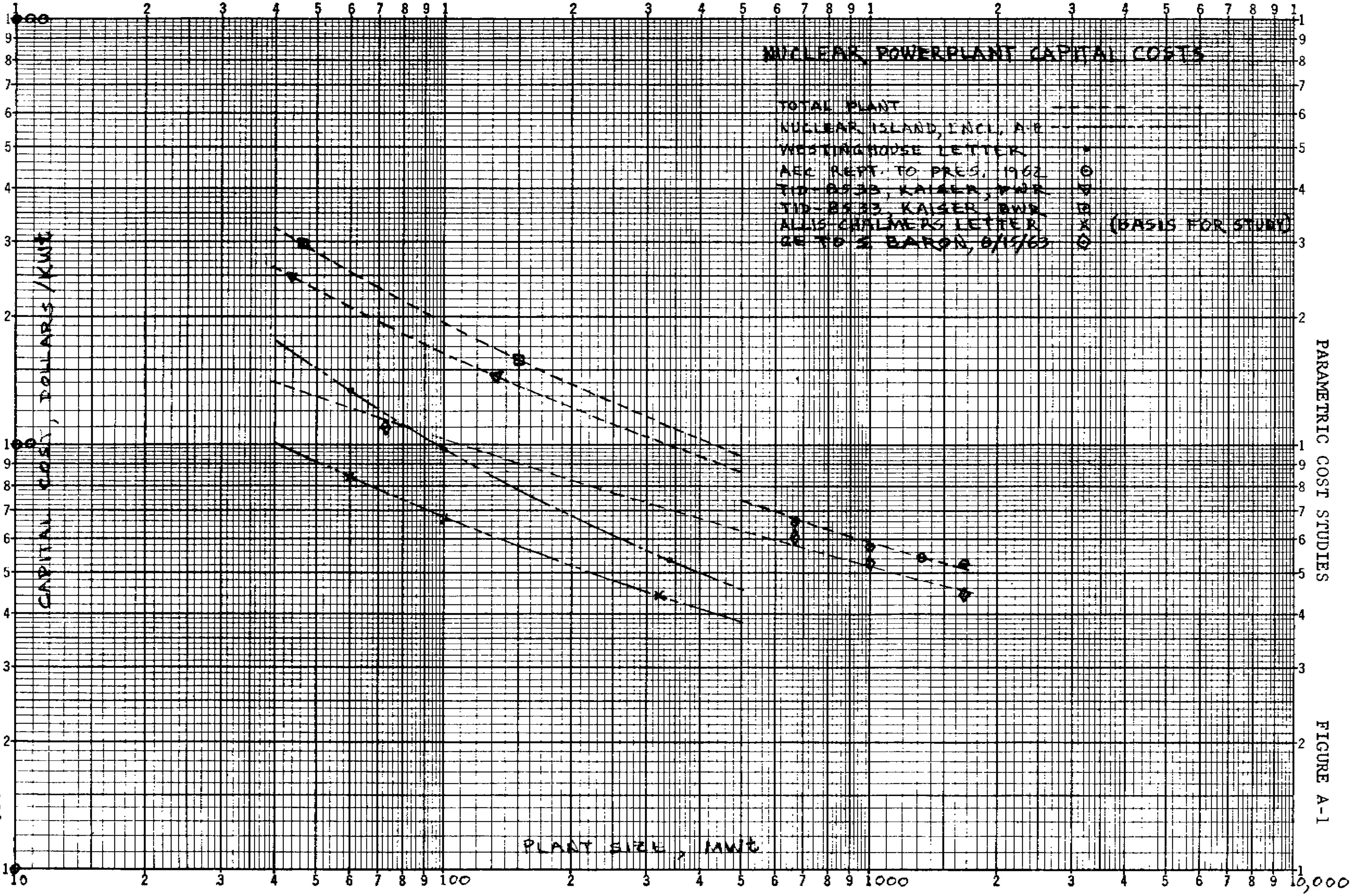
Babcock & Wilcox Company	General Electric Company
Combustion Engineering	Westinghouse Electric Corporation



PARAMETRIC COST STUDIES

FIGURE A-1

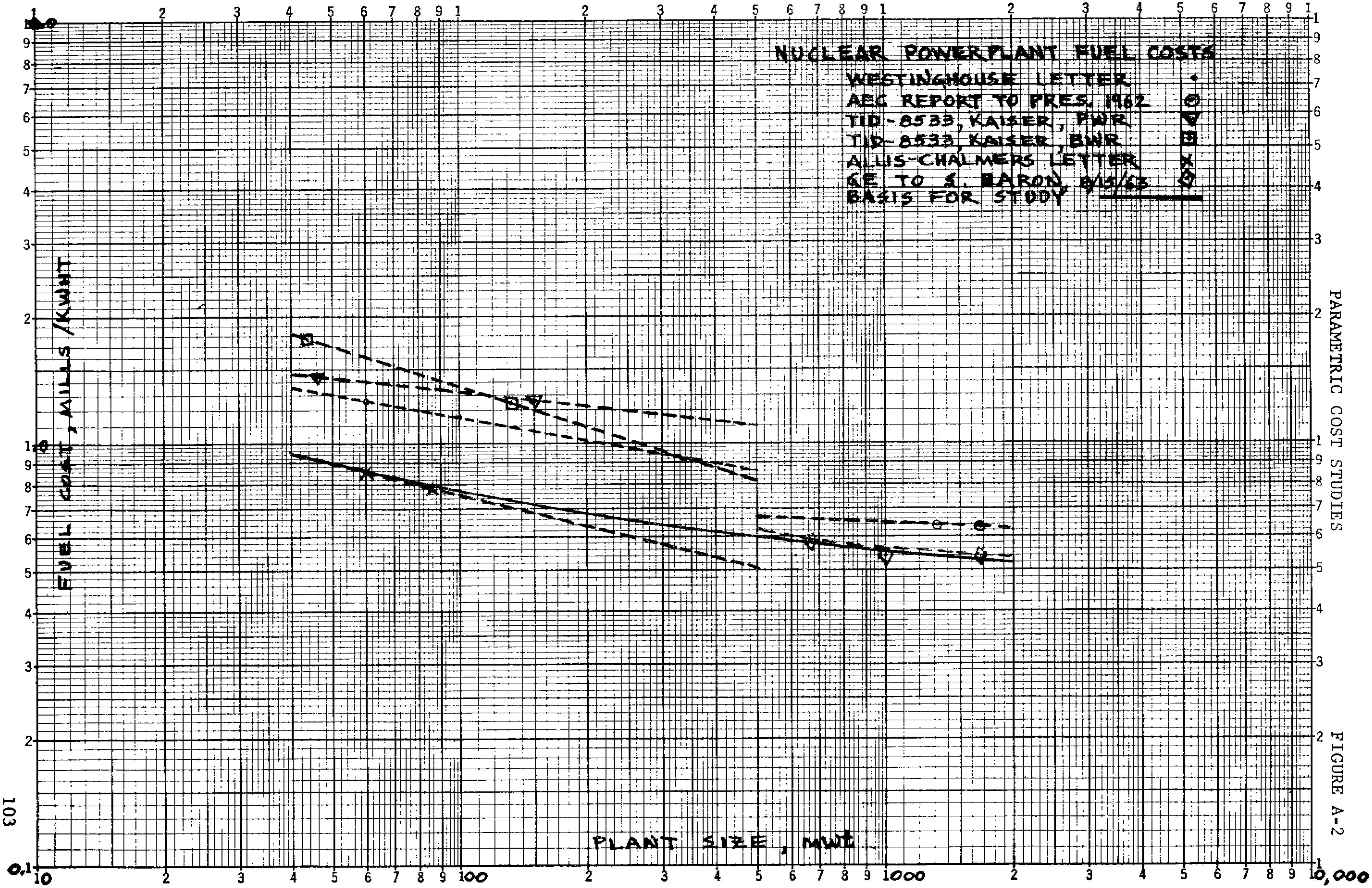

NUCLEAR POWERPLANT FUEL COSTS
WESTINGHOUSE LETTER
AEC REPORT TO PRES. 1962
TID-8533, KAISER, PWR
TID-8533, KAISER, BWR
ALLIS-CHALMERS LETTER
GE TO S. BARON 8/15/63
BASIS FOR STUDY
FUEL COST, MILLS/KWHT
PLANT SIZE, MWt
10
100
1000
10,000
0.1
1.0

FIGURE A-2

PARAMETRIC COST STUDIES
ELECTRIC POWER GENERATION COSTS - FOSSIL-FUELED PLANTS

TABLE 16

CASE NO. →	15			16			17			18			19			20		
WATER PRODUCTION, MMGPD	1			7			14			1			7			14		
	TOTAL CAPITAL COST $\$10^3$	ANNUAL COST $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL COST $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL COST $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL COST $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL COST $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL COST $\$10^3$	UNIT COST MILLS/KWHR
A 20¢/10^6 Btu Fuel	15-A			16-A			17-A			18-A			19-A			20-A		
FIXED CHARGES																		
1. DEPRECIATING CAPITAL (1)	99	7.7 (1)	3.99	672	52.3	3.88	1,184	92.1	3.41	95.7	7.4	4.3	642	49.9	4.15	1,112	86.5	3.60
2. WORKING CAPITAL (2)	0.9	0.1 (2)	.05	2.7	0.2	0.01	4	0.2	0.01	0.9	0.1	.06	2.9	0.2	0.02	4	0.2	0.01
3. SUBTOTAL - ANNUAL FIXED CHARGES		7.8	4.04		52.5	3.89		92.3	3.42		7.5	4.36		50.1	4.17		86.7	3.61
OPERATING COSTS																		
4. OPERATING AND MAINTENANCE		9	4.67		24	1.78		35	1.3		9	5.23		26	2.16		35	1.46
5. STEAM COSTS		4.1	2.12		20.7	1.53		39.4	1.46		4.2	2.44		20.9	1.74		37.3	1.55
6. SUBTOTAL - OPERATING COSTS		13.1	6.79		44.7	3.31		74.4	2.76		13.2	7.67		46.9	3.90		72.3	3.01
7. TOTAL - ELECTRIC GENERATION COSTS		20.9	10.83		97.2	7.20		166.7	6.18		20.7	12.03		97.0	8.07		159.0	6.62
B 30¢/10^6 Btu Fuel	15-B			16-B			17-B			18-B			19-B			20-B		
FIXED CHARGES																		
1. DEPRECIATING CAPITAL (1)	99	7.7	3.99	672	52.3	3.88	1,184	92.1	3.41	95.7	7.4	4.3	642	49.9	4.15	1,112	86.5	3.60
2. WORKING CAPITAL (2)	0.9	0.1	.05	2.8	0.2	.01	4	0.2	0.01	0.9	0.1	.06	2.7	0.2	0.02	4	0.2	0.01
3. SUBTOTAL - ANNUAL FIXED CHARGES		7.8	4.04		52.5	3.89		92.3	3.42		7.5	4.36		50.1	4.17		86.7	3.61
OPERATING COSTS																		
4. OPERATING AND MAINTENANCE		9	4.66		23	1.71		30	1.11		9	5.23		22	1.83		30	1.25
5. STEAM COSTS		5.1	2.65		27.1	2.00		53.1	1.97		5.2	3.02		27.1	2.25		49.5	2.05
6. SUBTOTAL - OPERATING COSTS		14.1	7.31		50.1	3.71		83.1	3.08		14.2	8.25		49.1	4.08		79.5	3.30
7. TOTAL - ELECTRIC GENERATION COSTS		21.9	11.35		102.6	7.60		175.4	6.50		21.7	12.61		99.2	8.25		166.2	6.91
C 40¢/10^6 Btu Fuel	15-C			16-C			17-C			18-C			19-C			20-C		
FIXED CHARGES																		
1. DEPRECIATING CAPITAL (1)	99	7.7	3.99	672	52.3	3.88	1,184	92.1	3.41	95.7	7.4	4.3	642	49.9	4.15	1,112	86.5	3.60
2. WORKING CAPITAL (2)	1.0	0.1	.05	2.9	0.2	.01	4	0.2	.01	0.9	0.1	.06	2.9	0.2	0.02	4	0.2	.01
3. SUBTOTAL - ANNUAL FIXED CHARGES		7.8	4.04		52.5	3.89		92.3	3.42		7.5	4.36		50.1	4.17		86.7	3.61
OPERATING COSTS																		
4. OPERATING AND MAINTENANCE		9	4.29		22	1.63		29	1.07		8	4.65		22	1.83		30	1.25
5. STEAM COSTS		6.1	3.16		34.1	2.53		65.4	2.43		6.3	3.66		33.2	2.76		61.8	2.57
6. SUBTOTAL - OPERATING COSTS		15.1	7.82		56.1	4.16		94.4	3.50		14.3	8.31		55.2	4.59		91.8	3.82
7. TOTAL - ELECTRIC GENERATION COSTS		22.9	11.86		108.6	8.05		186.7	6.92		21.8	12.67		105.3	8.76		178.5	7.43

NOTES: (1) .0778 AMORTIZATION FACTOR
(2) .0565 AMORTIZATION FACTOR

PARAMETRIC COST STUDIES
ELECTRIC POWER GENERATION COSTS - NUCLEAR PLANTS

TABLE 15

CASE NO. →	1			2			3			4			5			6		
REACTOR POWER LEVEL, MWt WATER PRODUCTION, MMGPD NET POWER GENERATION, MWe KWHR/YEAR @ 80% CF	500 50 83.52 585.31 x 10^6			500 35 101.12 708.65 x 10^6			500 20 118.8 832.6 x 10^6			120 19.6 15.22 106.66 x 10^6			70 11.6 8.98 62.93 x 10^6			40 7.0 4.77 33.43 x 10^6		
	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR
1. DEPRECIATING CAPITAL (1) Turbogenerator Plant	11,440	907	1.55	12,830	1,017	1.44	14,440	1,145	1.38	3,553	282	2.64	2,594	206	3.27	1,604	127	3.80
2. NONDEPRECIATING CAPITAL (2) Working Capital	100	6	.01	110	6	.01	130	7	.01	37	2	.02	29	2	.03	23	1	.03
3. SUBTOTAL FIXED CHARGES		913	1.56		1,023	1.45		1,152	1.39		284	2.66		208	3.30		128	3.83
OPERATING COSTS																		
4. OPERATING AND MAINTENANCE		340	0.58		340	0.47		340	0.41		270	2.53		250	3.97		235	7.03
5. STEAM COST		2,233	3.82		2,862	4.04		3,527	4.23		367	3.44		269	4.28		198	5.92
6. SUBTOTAL - OPERATING COSTS		2,573	4.40		3,202	4.51		3,867	4.64		637	5.97		519	8.25		433	12.95
7. TOTAL - ELECTRIC GENERATION COST		3,486	5.96		4,225	5.96		5,019	6.03		921	8.63		727	11.55		561	16.78

CASE NO. →	7			8			9			10			11			12			13		
REACTOR POWER LEVEL, MWt WATER PRODUCTION, MMGPD NET POWER GENERATION, MWe KWHR/YEAR @ 80% CF	500 50 63.78 446.97 x 10^6			500 35 89.24 625.39 x 10^6			500 20 109.99 770.81 x 10^6			120 25.3 6.69 46.88 x 10^6			70 14.3 3.82 26.77 x 10^6			40 7.8 2.00 14.02 x 10^6			40 7.6 2.09 14.65 x 10^6		
	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST MILLS/KWHR
1. DEPRECIATING CAPITAL (1) Turbogenerator Plant	10,460	829	1.86	11,830	938	1.50	13,600	1,078	1.40	2,317	184	3.92	1,503	119	4.45	900	71	5.06	703	56	3.82
2. NONDEPRECIATING CAPITAL (2) Working Capital	100	6	0.01	110	6	0.01	130	7	0.01	28	2	0.04	24	1	0.03	20	1	.07	20	1	.07
3. SUBTOTAL FIXED CHARGES		835	1.87		944	1.51		1,085	1.41		186	3.96		120	4.48		72	5.13		57	3.89
OPERATING COSTS																					
4. OPERATING AND MAINTENANCE		340	0.76		340	0.54		340	0.44		270	5.76		250	9.34		235	16.76		235	16.04
5. STEAM COST		2,297	5.14		2,996	4.79		3,531	4.58		133	2.84		93	3.47		66	4.71		44	3.00
6. SUBTOTAL - OPERATING COSTS		2,637	5.90		3,336	5.33		3,871	5.02		403	8.60		343	12.81		301	21.83		279	19.04
7. TOTAL - ELECTRIC GENERATION COST		3,472	7.77		4,280	6.84		4,956	6.43		589	12.56		463	17.29		373	26.60		336	22.93

NOTES:

(1) AMORTIZATION FACTOR

.0793 for NUCLEAR
.0778 for FOSSIL

(2) AMORTIZATION FACTOR

.0580 for NUCLEAR
.0565 for FOSSIL

PARAMETRIC COST STUDIES
COST OF DESALINATED WATER

TABLE 18

CASE NO. →	1	2	3	4	5	6	7	8	9	10	11	12	13	14
WATER PRODUCTION, MMGPD	50	35	20	19.6	11.6	7	50	35	20	25.3	14.3	7.8	7.6	8.6
COST PER STREAM-DAY	$	$	$	$	$	$	$	$	$	$	$	$	$	$
ESSENTIAL OPERATING COST														
1. ELECTRIC POWER COST	1,967	1,377	796	1,113	884	777	2,284	1,408	756	1,870	1,452	1,213	1,150	355
2. STEAM COST	7,240	5,086	2,808	4,397	3,233	2,411	7,020	4,627	2,795	5,199	3,836	2,863	2,600	2,750
3. CHEMICALS	1,475	1,033	590	578	342	206	1,475	1,033	590	746	422	230	224	254
4. SUPPLIES AND MAINTENANCE	656	448	259	315	219	163	655	435	245	451	300	204	177	218
5. OPERATING LABOR	949	658	373	503	361	273	953	628	362	676	475	344	311	306
6. MAINTENANCE LABOR	656	448	259	315	219	163	655	435	245	434	300	204	177	218
7. PAYROLL EXTRAS	241	166	95	123	87	65	241	159	91	167	116	82	73	79
SUBTOTAL - ESSENTIAL OPERATING COSTS	13,184	9,216	5,180	7,344	5,345	4,058	13,283	8,725	5,084	9,543	6,901	5,140	4,712	4,180
OTHER OPERATING COSTS														
8. GENERAL AND ADMINISTRATIVE OVERHEAD	277	191	109	140	100	75	277	183	105	192	134	95	84	90
9. AMORTIZATION	7,638	5,221	3,012	3,670	2,546	1,904	7,626	5,065	2,856	5,250	3,493	2,378	2,064	2,537
10. TAXES, INSURANCE AND INTERIM REPLACEMENT	2,643	1,806	1,042	1,269	881	659	2,638	1,752	988	1,816	1,209	823	714	878
11. INTEREST ON WORKING CAPITAL	195	135	77	102	73	55	196	129	74	138	93	69	62	63
TOTAL - OPERATING COST (PER STREAM-DAY)	23,937	16,569	9,420	12,525	8,945	6,751	24,020	15,854	9,107	16,939	11,830	8,505	7,636	7,748
	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal
UNIT COST OF PRODUCT WATER	47.9	47.3	47.1	63.9	77.1	96.4	48.0	45.3	45.5	67.0	82.7	109.0	100.5	90.1

CASE NO. →	15-A	15-B	15-C	16-A	16-B	16-C	17-A	17-B	17-C	18-A	18-B	18-C	19-A	19-B	19-C	20-A	20-B	20-C
WATER PRODUCTION, MMGPD	1 (20¢ Fuel)	1 (30¢ Fuel)	1 (40¢ Fuel)	7 (20¢ Fuel)	7 (30¢ Fuel)	7 (40¢ Fuel)	14 (20¢ Fuel)	14 (30¢ Fuel)	14 (40¢ Fuel)	1 (20¢ Fuel)	1 (30¢ Fuel)	1 (40¢ Fuel)	7 (20¢ Fuel)	7 (30¢ Fuel)	7 (40¢ Fuel)	14 (20¢ Fuel)	14 (30¢ Fuel)	14 (40¢ Fuel)
COST PER STREAM-DAY	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
ESSENTIAL OPERATING COST																		
1. ELECTRIC POWER COST	71	75	78	333	351	372	571	600	639	71	74	75	332	340	361	545	569	612
2. STEAM COST	325	374	412	1,538	1,829	2,085	2,699	3,257	3,767	333	378	426	1,551	1,839	2,099	2,593	3,093	3,535
3. CHEMICALS	30	30	30	207	207	207	413	413	413	30	30	30	207	207	207	413	413	413
4. SUPPLIES AND MAINTENANCE	28	28	28	124	137	150	220	247	273	28	28	28	137	150	164	220	247	287
5. OPERATING LABOR	39	41	44	182	206	228	323	369	421	39	42	44	191	214	237	317	360	409
6. MAINTENANCE LABOR	28	28	28	124	137	150	220	247	273	28	28	28	137	150	164	220	247	287
7. PAYROLL EXTRAS	10	11	11	46	51	57	81	92	104	10	11	11	49	55	60	81	91	104
SUBTOTAL - ESSENTIAL OPERATING COSTS	531	587	631	2,554	2,918	3,249	4,527	5,225	5,890	539	591	642	2,604	2,955	3,292	4,389	5,020	5,647
OTHER OPERATING COSTS																		
8. GENERAL AND ADMINISTRATIVE OVERHEAD	12	12	12	53	59	65	94	106	120	12	12	12	57	63	69	93	105	120
9. AMORTIZATION	325	325	325	1,440	1,596	1,752	2,559	2,871	3,327	325	325	325	1,596	1,752	1,909	2,559	2,871	3,341
10. TAXES, INSURANCE AND INTERIM REPLACEMENT	112	112	112	498	552	606	885	993	1,102	112	112	112	552	606	660	885	993	1,156
11. INTEREST ON WORKING CAPITAL	8	9	9	37	42	47	66	75	86	8	9	9	39	44	49	65	74	84
TOTAL - OPERATING COST (PER STREAM-DAY)	988	1,045	1,089	4,582	5,167	5,719	8,131	9,270	10,525	996	1,049	1,100	4,848	5,420	5,979	7,991	9,063	10,348
	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal	¢/1000 gal
UNIT COST OF PRODUCT WATER	98.8	104.5	108.9	65.5	73.8	81.7	58.1	66.2	75.2	99.6	104.9	110.0	69.3	77.4	85.4	57.1	64.7	73.9

PARAMETRIC COST STUDIES
WATER DESALINATION PLANT CAPITAL INVESTMENT COSTS

TABLE 17

CASE NO. →	1	2	3	4	5	6	7	8	9	10	11	12	13	14
WATER PRODUCTION, MMGPD	50 $\$10^3$	35 $\$10^3$	20 $\$10^3$	19.6 $\$10^3$	11.6 $\$10^3$	7.0 $\$10^3$	50 $\$10^3$	35 $\$10^3$	20 $\$10^3$	25.3 $\$10^3$	14.3 $\$10^3$	7.8 $\$10^3$	7.6 $\$10^3$	8.6 $\$10^3$
1. PRINCIPAL ITEMS OF EQUIPMENT	24,000	16,500	9,500	11,500	8,000	6,000	24,000	16,000	9,000	16,500	11,000	7,500	6,500	8,000
2. ERECTION AND ASSEMBLY	5,520	3,795	2,190	2,650	1,840	1,380	5,520	3,680	2,070	3,795	2,530	1,730	1,495	1,840
3. INSTRUMENTS	600	413	238	288	200	150	600	400	230	413	275	188	163	200
SUBTOTAL (1-3) ESSENTIAL PLANT COSTS	30,120	20,708	11,928	14,438	10,040	7,530	30,120	20,080	11,300	20,708	13,805	9,418	8,158	10,040
4. RAW WATER SUPPLY	493	206	118	264	157	94	444	206	118	341	193	106	102	116
5. SERVICE FACILITIES AND BUILDING	42	42	42	21	22	18	42	42	42	21	22	18	24	24
SUBTOTAL (1-5)	30,655	20,956	12,088	14,723	10,219	7,642	30,606	20,328	11,460	21,070	14,020	9,542	8,284	10,180
6. CONTINGENCIES	3,066	2,096	1,209	1,472	1,022	764	3,061	2,033	1,146	2,107	1,402	954	828	1,018
7. ENGINEERING	3,372	2,305	1,330	1,620	1,124	841	3,367	2,236	1,261	2,318	1,542	1,050	911	1,120
8. INTEREST DURING CONSTRUCTION	1,484	1,014	585	713	495	370	1,481	984	555	1,020	679	462	401	493
TOTAL	38,577	26,371	15,212	18,528	12,860	9,617	38,515	25,581	14,422	26,515	17,643	12,008	10,424	12,811

CASE NO. →	15-A 1	15-B 1	15-C 1	16-A 7	16-B 7	16-C 7	17-A 14	17-B 14	17-C 14	18-A 1	18-B 1	18-C 1	19-A 7	19-B 7	19-C 7	20-A 14	20-B 14	20-C 14
WATER PRODUCTION, MMGPD	(20¢ Fuel) $\$10^3$	(30¢ Fuel) $\$10^3$	(40¢ Fuel) $\$10^3$	(20¢ Fuel) $\$10^3$	(30¢ Fuel) $\$10^3$	(40¢ Fuel) $\$10^3$	(20¢ Fuel) $\$10^3$	(30¢ Fuel) $\$10^3$	(40¢ Fuel) $\$10^3$	(20¢ Fuel) $\$10^3$	(30¢ Fuel) $\$10^3$	(40¢ Fuel) $\$10^3$	(20¢ Fuel) $\$10^3$	(30¢ Fuel) $\$10^3$	(40¢ Fuel) $\$10^3$	(20¢ Fuel) $\$10^3$	(30¢ Fuel) $\$10^3$	(40¢ Fuel) $\$10^3$
1. PRINCIPAL ITEMS OF EQUIPMENT	1,000	1,000	1,000	4,500	5,000	5,500	8,000	9,000	10,000	1,000	1,000	1,000	5,000	5,500	6,000	8,000	9,500	10,500
2. ERECTION AND ASSEMBLY	230	230	230	1,035	1,150	1,265	1,840	2,070	2,300	230	230	230	1,150	1,265	1,380	1,840	2,185	2,415
3. INSTRUMENTS	25	25	25	113	125	138	200	225	250	25	25	25	125	138	150	200	238	263
SUBTOTAL (1-3) ESSENTIAL PLANT COSTS	1,255	1,255	1,255	5,648	6,275	6,903	10,040	11,295	12,550	1,255	1,255	1,255	6,275	6,903	7,530	10,040	11,923	13,178
4. RAW WATER SUPPLY	14	14	14	94	94	94	189	189	189	14	14	14	94	94	94	189	189	189
5. SERVICE FACILITIES AND BUILDING	35	35	35	36	36	36	40	40	40	35	35	35	36	36	36	40	40	40
SUBTOTAL (1-5)	1,304	1,304	1,304	5,778	6,405	7,033	10,269	11,524	12,779	1,304	1,304	1,304	6,405	7,033	7,660	10,269	12,152	13,407
6. CONTINGENCIES	130	130	130	578	641	703	1,027	1,152	1,278	130	130	130	641	703	766	1,027	1,215	1,341
7. ENGINEERING	143	143	143	636	705	774	1,130	1,268	1,406	143	143	143	705	774	843	1,130	1,337	1,475
8. INTEREST DURING CONSTRUCTION	63	63	63	280	310	340	497	558	619	63	63	63	310	340	371	497	588	649
TOTAL	1,640	1,640	1,640	7,272	8,061	8,850	12,923	14,502	16,082	1,640	1,640	1,640	8,061	8,850	9,640	12,923	15,292	16,872

TABLE 14

PARAMETRIC COST STUDIES
STEAM GENERATION COSTS - FOSSIL-FUELED PLANTS

CASE NO.	15			16			17			18			19			20		
WATER PRODUCTION - MMGPD	1			7			14			1			7			14		
	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb
A 20¢/10^6Btu Fuel	15-A			16-A			17-A			18-A			19-A			20-A		
FIXED CHARGES																		
1. DEPRECIATING CAPITAL																		
a) Total Capital Costs (1)	227	17.7	9.6	1,193	92.8	7.9	2,160	168	7.7	287	23.3	12.2	1,422	111	8.9	2,203	171	7.5
2. WORKING CAPITAL (2)	4	0.2	0.1	16	0.9	0.1	26	1.4	0.1	4	0.2	0.1	16	0.9	0.1	25	1.4	0.1
3. SUBTOTAL - ANNUAL FIXED CHARGES		17.9	9.7		93.7	8.0		169.4	7.8		23.5	12.3		111.9	9.0		172.4	7.6
OPERATING COSTS																		
4. OPERATING AND MAINTENANCE		35	19.1		96	8.2		135	6.2		34	17.8		94	7.5		130	5.7
5. FUEL COSTS		46.3	25.2		280	23.9		523	23.9		43	22.6		271	21.7		492	21.7
6. SUBTOTAL - OPERATING COST		81.3	44.3		376	32.1		658	30.1		77	40.4		365	29.2		622	27.4
7. TOTAL - STEAM GENERATION COSTS		99.2	54.0		469.7	40.1		827.4	37.9		100.5	52.7		476.9	38.2		794.4	35.0
B 30¢/10^6Btu Fuel	15-B			16-B			17-B			18-B			19-B			20-B		
FIXED CHARGES																		
1. DEPRECIATING CAPITAL																		
a) Total Capital Costs (1)	215	16.7	10.0	1,092	85.0	8.0	1,998	155.4	7.8	275	21.4	12.1	1,303	101	8.8	2,033	158	7.7
2. WORKING CAPITAL (2)	5	0.3	.2	19	1.1	0.1	31	1.7	0.1	5	0.3	0.2	18	1.0	0.1	29	1.6	0.1
3. SUBTOTAL - ANNUAL FIXED CHARGES		17.0	10.2		86.1	8.1		157.1	7.9		21.7	12.3		102	8.9		159.6	7.8
OPERATING COSTS																		
4. OPERATING AND MAINTENANCE		34	20.3		92	8.6		130	6.5		33	18.6		90	7.9		125	6.1
5. FUEL COSTS		63.3	37.8		383	35.9		717	35.9		61	34.4		372	32.6		668	32.5
6. SUBTOTAL - OPERATING COSTS		97.3	58.1		475	44.5		847	42.4		94	53.0		462	40.5		793	38.6
7. TOTAL - STEAM GENERATION COSTS		114.3	68.3		561.1	52.6		1,004.1	50.3		115.7	65.3		564	49.4		952.6	46.4
C 40¢/10^6Btu Fuel	15-C			16-C			17-C			18-C			19-C			20-C		
FIXED CHARGES																		
1. DEPRECIATING CAPITAL																		
a) Total Capital Costs (1)	202	15.7	10.1	1,012	78.7	7.9	1,869	145.4	7.8	275	21.4	12.8	1,219	95	8.9	1,896	148	7.8
2. WORKING CAPITAL (2)	5	0.3	0.2	21	1.2	0.1	35	2.0	0.1	5	0.3	0.2	20	1.1	0.1	33	1.9	0.1
3. SUBTOTAL - ANNUAL FIXED CHARGES		16.0	10.3		79.9	8.0		147.4	7.9		21.7	13.0		96.1	9.0		149.9	7.9
OPERATING COSTS																		
4. OPERATING AND MAINTENANCE		32	20.6		88	8.9		125	6.7		32	19.1		86	8.0		120	6.3
5. FUEL COSTS		78.5	50.4		475	47.8		893	47.9		77	46.0		464	43.4		824	43.4
6. SUBTOTAL - OPERATING COSTS		110.5	71.0		563	56.7		1,018	54.6		109	65.1		550	51.4		944	49.7
7. TOTAL - STEAM GENERATION COSTS		126.5	81.3		642.9	64.7		1,165.4	62.5		130.7	78.1		646.1	60.4		1,093.9	57.6

NOTES:

AMORTIZATION FACTORS

(1) .0778
(2) .0565

PARAMETRIC COST STUDIES
FOSSIL PLANTS COST ESTIMATES

TABLE 8

ACCOUNT NO.	CASE NO.	15-A	15-B	15-C	16-A	16-B	16-C	17-A	17-B	17-C	18-A	18-B	18-C	19-A	19-B	19-C	20-A	20-B	20-C
	WATER PRODUCTION, MMGPD	1.0			7.0			14.0			1.0			7.0			14.0		
	ELECTRIC GENERATION - KWe GROSS	300			2100			4200			290			2000			3900		
	TOTAL POUNDS OF STEAM FOR 3 BOILERS	42,000	39,000	36,000	264,000	240,000	222,000	492,000	450,000	420,000	42,000	39,000	39,000	292,000	258,000	240,000	510,000	462,000	426,000
	BRINE TEMPERATURE, °F	250									350								
	ITEM																		
321	STRUCTURES AND IMPROVEMENTS (Including Portion of Common Site Facilities)	33.0	33.0	33.0	235.5	235.5	235.5	465.1	465.1	465.1	33.0	33.0	33.0	235.5	235.5	235.5	465.1	465.1	465.1
322	POWER PLANT	128.7	119.6	109.7	795.2	720.0	659.1	1,461.2	1,338.0	1,242.1	172.8	164.0	164.0	951.9	862.3	802.8	1,467.7	1,338.0	1,235.0
323	TURBOGENERATOR UNITS	37.0	37.0	37.0	163.0	163.0	163.0	273.0	273.0	273.0	35.3	35.3	35.3	156.0	156.0	156.0	250.0	250.0	250.0
324	ACCESSORY ELECTRICAL EQUIPMENT	12.5	12.5	12.5	84.8	84.8	84.8	168.0	168.0	168.0	12.0	12.0	12.0	80.0	80.0	80.0	162.0	162.0	162.0
325	MISCELLANEOUS POWER PLANT EQUIP.	18.0	18.0	18.0	87.0	87.0	87.0	120.0	120.0	120.0	18.0	18.0	18.0	87.0	87.0	87.0	120.0	120.0	120.0
	OTHER EXPENSES	15.0	15.0	15.0	63.0	59.0	58.0	85.0	83.0	80.0	15.0	15.0	15.0	70.0	68.0	62.0	85.0	83.0	80.0
	SUBTOTAL	244.2	235.1	225.2	1,428.5	1,349.3	1,287.4	2,572.3	2,447.1	2,348.2	286.1	277.3	277.3	1,580.4	1,488.8	1,423.3	2,549.8	2,418.1	2,312.1
	ENGINEERING, FIELD SUPERVISION, CONSTRUCTION MANAGEMENT, INTEREST, CONTINGENCY	81.6	78.4	75.4	436.8	414.7	396.9	772.0	735.3	705.2	96.5	93.4	93.4	483.6	456.1	437.9	764.9	726.2	695.1
	TOTAL PLANT COST	325.8	313.5	300.6	1,865.3	1,764.0	1,684.3	3,344.3	3,182.4	3,053.4	382.6	370.7	370.7	2,064.0	1,944.9	1,861.2	3,314.7	3,144.3	3,007.2

NOTE: All costs listed in $\$10^3$ except \$/kw

PARAMETRIC COST STUDIES
NUCLEAR REACTOR PLANT COST ESTIMATES

TABLE 7

ACCOUNT NO.	ITEM	1	2	3	4	5	6	7	8	9	10	11	12		13	14
	REACTOR RATING MWt	500			120	70	40	500			120	70	40		40	40
	WATER PRODUCTION MMGPD	50.0	35.0	20.0	19.6	11.6	7.0	50.0	35.0	20.0	25.3	14.3	7.8		7.6	8.6
	ELECTRIC GENERATION -MWe GROSS	95,400	113,300	131,300	18,000	10,600	5,700	75,700	101,500	122,500	9,400	5,400	2,900		2,210	- 0 -
	BRINE TEMPERATURE, °F	250						350							250	350
321	STRUCTURES AND IMPROVEMENTS (TURBOGENERATOR PORTION ONLY)															
	Common Site Facilities	92.0	92.0	92.0	44.0	39.0	38.0	92.0	92.0	92.0	24.0	19.0	18.0		12.0	-
	Turbine Plant	995.2	1,103.6	1,355.0	288.0	180.2	96.9	910.0	1,095.0	1,272.0	159.8	91.8	55.1		48.0	50.0
															42.8	-
	Reactor Plant	-	-	-	-	-	-	-	-	-	-	-	-		590.0	590.0
322	REACTOR PLANT EQUIPMENT															
	Power Plant Equipment	1,985.0	2,202.8	2,550.0	900.0	614.0	342.0	1,750.0	2,060.0	2,441.0	539.4	323.0	204.0		158.3	-
	Reactor Plant Equipment	-	-	-	-	-	-	-	-	-	-	-	-		1,520.0	1,520.0
323	TURBOGENERATOR UNITS	4,228.0	4,734.8	5,350.0	900.0	667.0	399.0	3,850.0	4,321.1	5,016.3	586.4	373.0	212.0		164.5	-
324	ACCESSORY ELECTRIC EQUIPMENT	915.0	1,145.1	1,192.8	252.0	212.0	142.5	840.0	956.3	1,122.0	200.0	135.0	77.5		60.2	-
325	MISCELLANEOUS POWER PLANT EQUIPMENT	160.0	170.0	193.0	90.0	75.0	57.0	140.0	156.0	180.0	75.0	57.0	30.0		25.0	-
353	SUBSTATION EQUIPMENT	840.0	932.7	1,110.0	216.0	159.0	114.0	770.0	896.0	1,028.0	141.0	110.0	50.0		35.0	-
-	OTHER EXPENSES	160.0	170.0	193.0	90.0	75.0	57.0	140.0	156.0	180.0	75.0	55.0	50.0		40.0	-
	SUBTOTAL $	9,375.2	10,551.0	12,035.8	2,780.0	2,021.2	1,246.4	8,492.0	9,732.4	11,331.3	1,800.6	1,163.8	696.6	Subtotal N	2,155.0	2,160.3
														Subtotal P	540.8	
														Subtotal	2,695.8	2,160.3
	ENGINEERING, FIELD SUPERVISION, CONSTRUCTION MANAGEMENT, CONSTRUCTION INTEREST, CONTINGENCY	2,062.5	2,279.0	2,407.2	772.9	572.9	357.1	1,968.0	2,092.4	2,266.2	516.5	338.9	203.6	N %	848.0	842.7
														P %	162.2	-
														Subtotal %	1,010.2	842.7
	TOTAL PLANT COST - $	11,437.7	12,830.0	14,443.0	3,552.9	2,594.1	1,603.5	10,460.0	11,824.8	13,597.5	2,317.1	1,502.7	900.2	Total N	3,003.0	3,003.0
														Total P	703.0	-
														Total	3,706.0	3,003.0

NOTE: All costs listed in $\$10^3$ except \$/kw.

PARAMETRIC COST STUDIES
SITE COSTS

TABLE 6

CASE NO. →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ITEM																				
SITE CLEARING																				
Nuclear Reactor	$ 7,000	$ 7,000	$ 7,000	$ 4,000	$ 3,000	$ 3,000	$ 7,000	$ 7,000	$ 7,000	$ 4,000	$ 3,000	$ 3,000	$ 2,000	$ 3,000	$ -	$ -	$ -	$ -	$ -	$ -
Power Plant (Turbogenerator)	7,000	7,000	7,000	3,000	2,000	1,000	7,000	7,000	7,000	3,000	2,000	1,000	1,000	-	-	-	-	-	-	-
Water Plant	7,000	7,000	7,000	2,000	2,000	1,000	7,000	7,000	7,000	2,000	2,000	1,000	2,000	2,000	1,000	2,000	3,000	1,000	2,000	3,000
TOTAL	$ 21,000	$ 21,000	$ 21,000	$ 9,000	$ 7,000	$ 5,000	$21,000	$21,000	$21,000	$ 9,000	$ 7,000	$ 5,000	$ 5,000	$ 5,000	$ 1,000	$ 2,000	$ 3,000	$ 1,000	$ 2,000	$ 3,000
ROADS AND WALKS																				
Nuclear Reactor	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 6,000	$ 6,000	$ -	$ -	$ -	$ -	$ -	$ -
Power Plant (Turbogenerator)	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	-	-	-	-	-	-	-	-
Water Plant	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	6,000	6,000	12,000	12,000	12,000	12,000	12,000	12,000
TOTAL	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$ 12,000	$ 12,000	$ 12,000	12,000	$ 12,000	$ 12,000
RAILROADS																				
Nuclear Reactor	$ 30,000	$ 30,000	$ 30,000	$ 60,000	$ 60,000	$ 60,000	$30,000	$30,000	$30,000	$60,000	$60,000	$60,000	-	-	$ -	-	-	-	-	-
Power Plant (Turbogenerator)	30,000	30,000	30,000	-	-	-	30,000	30,000	30,000	-	-	-	-	-	-	-	-	-	-	-
TOTAL	$ 60,000	$ 60,000	$ 60,000	$ 60,000	$ 60,000	$ 60,000	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	- 0 -	- 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -
LAND COSTS	← Included in Either Nuclear Reactor or Water Plant Costs →																			
FENCES																				
Nuclear Reactor	$ 11,000	$ 11,000	$ 11,000	$ 9,000	$ 9,000	$ 10,000	$11,000	$11,000	$11,000	$ 9,000	$ 9,000	$10,000	$ 9,000	$10,000	$ -	$ -	$ -	$ -	$ -	$ -
Power Plant (Turbogenerator)	11,000	11,000	11,000	7,000	3,000	3,000	11,000	11,000	11,000	7,000	3,000	3,000	1,000	-	-	-	-	-	-	-
Water Plant	11,000	11,000	11,000	5,000	6,000	3,000	11,000	11,000	11,000	5,000	6,000	3,000	6,000	6,000	7,000	9,000	14,000	7,000	9,000	14,000
TOTAL	$ 33,000	$ 33,000	$ 33,000	$ 21,000	$ 18,000	$ 16,000	$33,000	$33,000	$33,000	$21,000	$18,000	$16,000	$16,000	$16,000	7,000	9,000	14,000	7,000	9,000	14,000
SERVICE BUILDING																				
Nuclear Reactor	$ 50,000	$ 50,000	$ 50,00	$ 40,000	$ 30,000	$ 20,000	$50,000	$50,000	$50,000	$40,000	$30,000	$20,000	$20,000	$20,000	$ -	$ -	$ -	$ -	$ -	$ -
Power Plant (Turbogenerator)	40,000	40,000	40,000	30,000	30,000	30,000	40,000	40,000	40,000	10,000	10,000	10,000	10,000	-	-	-	-	-	-	-
Water Plant	20,000	20,000	20,000	10,000	10,000	10,000	20,000	20,000	20,000	10,000	10,000	10,000	10,000	10,000	20,000	20,000	20,000	20,000	20,000	20,000
TOTAL	$110,000	$110,000	$110,000	$ 80,000	$ 70,000	$ 60,000	$110,000	$110,000	$110,000	$60,000	$50,000	$40,000	$40,000	$30,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000
GUARDHOUSE																				
Nuclear Reactor only, no Power or Water	$ 20,000	$ 20,000	$ 20,000	$ 14,000	$ 12,000	$ 11,000	$20,000	$20,000	$20,000	$14,000	$12,000	$11,000	$11,000	$11,000	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 20,000	$ 20,000	$ 20,000	$ 14,000	$ 12,000	$ 11,000	$20,000	$20,000	$20,000	$14,000	$12,000	$11,000	$11,000	$11,000	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -	$ - 0 -
TOTAL COMMON SITE FACILITIES															← (Arbitrary - Divisions) →					
Nuclear Reactor	$122,000	$122,000	$122,000	$131,000	$118,000	$108,000	$122,000	$122,000	$122,000	$131,000	$118,000	$108,000	$48,000	$50,000	B-$ 3,000	B-$ 4,000	B-$ 5,000	B-$ 3,000	B-$ 4,000	B-$ 5,000
Power Plant (Turbogenerator)	92,000	92,000	92,000	44,000	39,000	38,000	92,000	92,000	92,000	24,000	19,000	18,000	12,000	-	P- 2,000	P- 3,000	P- 4,000	P- 2,000	P- 3,000	P- 4,000
Water Plant	42,000	42,000	42,000	21,000	22,000	18,000	42,000	42,000	42,000	21,000	22,000	18,000	24,000	24,000	W- 35,000	W- 36,000	W- 40,000	W- 35,000	W- 36,000	W- 40,000
GRAND TOTAL	$256,000	$256,000	$256,000	$196,000	$179,000	$164,000	$256,000	$256,000	$256,000	$176,000	$159,000	$144,000	$84,000	$74,000	$40,000	$43,000	$49,000	$40,000	$43,000	$49,000

B - Boiler
P - Power Plant (Turbogenerator)
W - Water Plant

PARAMETRIC COST STUDIES
SUMMARY OF CASES AND PERFORMANCE DATA
FOSSIL-FUEL PLANTS

TABLE 4

CASE NO.		15			16			17			18			19			20		
	UNITS	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
BRINE HEATER TEMPERATURE	°F	250									350								
WATER PRODUCTION	10^6 gal/day	1			7			14			1			7			14		
GROSS ELECTRIC GENERATION	kw	300			2100			4200			290			2000			3900		
AUXILIARY POWER REQUIRED FOR DESALINATION PLANT (1)	kw	275			1925			3850			245			1715			3430		
FUEL COST	¢/10^6Btu	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
STEAM COST TO BRINE HEATER	¢/1000 lb	51.8	65.2	77.4	38.3	50.0	61.3	36.1	47.6	59.0	50.5	62.4	74.4	36.5	47.0	57.3	33.4	44.0	54.3
ELECTRICITY COST	mills/kwhr	10.83	11.35	11.86	7.20	7.60	8.05	6.18	6.50	6.92	12.03	12.61	12.67	8.07	8.25	8.76	6.62	6.91	7.43
CALCULATED PERFORMANCE RATIO (2)	lb H_2O/lb Steam	13.5	15.1	16.3	14.9	16.4	17.6	15.9	17.5	18.8	13.2	14.2	15.2	14.1	15.5	16.6	15.6	17.3	18.8
PERFORMANCE RATIO USED FOR HEAT BALANCE AND COST ESTIMATE (2)	lb H_2O/lb Steam	13.4	14.8	16.0	14.8	16.3	17.6	15.9	17.5	18.8	13.2	14.2	15.1	14.1	15.5	16.6	15.6	17.3	18.8
ACTUAL PERFORMANCE RATIO (3)	lb H_2O/lb Steam	13.3	14.5	15.6	14.6	16.0	17.2	15.6	17.1	18.3	12.8	13.7	14.5	13.6	14.9	15.9	15.0	16.6	17.9
STEAM FLOW FROM BOILER	lb/hr	26,200	23,900	22,200	167,000	152,400	141,700	312,000	284,800	266,200	27,200	25,300	23,900	178,400	163,000	152,700	323,600	293,300	271,100
FUEL FIRED	10^6Btu/hr	33	30.1	28.0	199.8	182.4	169.6	373.3	340.8	318.5	31	28.9	27.3	193.4	176.7	165.5	350.7	317.9	293.8
EQUIVALENT MW OUTPUT (4)	mw	7.3	6.7	6.2	46.8	42.7	39.7	87.5	79.9	74.7	6.9	6.4	6.1	45.3	41.4	38.8	82.2	74.5	68.9
DESIGN MAXIMUM CONTINUOUS CAPACITY OF BOILERS FOR COST ESTIMATE	lb/hr	14,000	13,000	12,000	88,000	80,000	74,000	164,000	150,000	140,000	14,000	13,000	13,000	94,000	86,000	80,000	170,000	154,000	142,000

NOTES:

1. Auxiliary power required for desalination plant based on 275 kw/10^6 gal for 250°F brine heater temperature and 245 kw/10^6 gal for 350°F brine heater temperature and rounded to nearest 10 kw.
2. Performance ratio based on saturated steam at brine heater - not on calculated steam condition.
3. Performance ratio based on calculated steam condition at brine heater.
4. Equivalent mw output = $\frac{(\text{boiler steam flow in lb/hr}) \times (\Delta H \text{ across boiler})}{3412.75 \times 10^3}$

PARAMETRIC COST STUDIES
SUMMARY OF CASES AND PERFORMANCE DATA
NUCLEAR PRESSURIZED-WATER REACTOR PLANTS

TABLE 3

CASE NO. →	UNITS	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TYPE OF PLANT		← DUAL PURPOSE →												← SINGLE PURPOSE →	
BRINE TEMPERATURE	°F	← 250 →						← 350 →						250	350
REACTOR RATING	MWt	← 500 →			120	70	40	← 500 →			120	70	40	40	40
WATER PRODUCTION	10^6 gal/day	50	35	20	19.6	11.6	7.0	50	35	20	25.3	14.3	7.8	7.6	8.6
PERFORMANCE DATA															
Turbine Type	-	← Condensing →			← Noncondensing →			← Condensing →			← Noncondensing →			Noncondensing	None
Gross Generator Output	kw	95,400	113,300	131,300	18,000	10,600	5,700	75,700	101,500	122,500	9,400	5,400	2,900	2,210	-
Auxiliary Power Required for Desalination Plant (1)	kw	13,750	9,630	5,500	5,390	3,190	1,930	12,250	8,580	4,900	6,200	3,500	1,900	2,090	2,110 (2)
Auxiliary Power Required for Reactor - Turbine Plant	kw	11,880	12,180	12,500	2,780	1,620	930	11,920	12,260	12,510	2,710	1,580	900	120	100 (2)
Total Auxiliary Power	kw	25,630	21,810	18,000	8,170	4,810	2,860	24,170	20,840	17,410	8,910	5,080	2,800	2,210	2,210 (2)
Net Electric Power Available	kw	69,770	91,490	113,300	9,830	5,790	2,840	51,530	80,660	105,090	490	320	100	-	-
Steam Flow from Steam Generator	lb/hr	← 1,935,000 →			464,000	271,000	155,000	← 1,935,000 →			472,000	276,000	157,000	142,800	158,800
Steam Flow to Brine Heater	lb/hr	1,169,000	818,400	452,600	422,450	246,730	141,190	1,323,500	876,300	529,400	472,000	276,000	157,000	142,800	158,800
Steam Cost at Brine Heater	¢/1000 lb	25.8	25.9	25.9	43.4	54.6	71.1	22.1	22.0	22.0	45.9	57.9	76	75.9	72.2
Electricity Cost	mills/kwhr	5.76	5.96	6.03	8.63	11.55	16.78	7.77	6.84	6.43	12.56	17.29	26.60	22.93	7
Calculated Performance Ratio (3)	lb H_2O/lb steam	14.5	15.1	14.6	17.5	17.9	18.6	14.5	14.8	14.0	20.0	19.2	18.6	19.1	18.7
Performance Ratio Used for Heat Balance and Cost Estimate (3)	lb H_2O/lb steam	15	15.0	15.5	18.2	18.5	19.2	14.0	14.8	14.0	20.0	19.2	18.5	19.1	18.9
Actual Performance Ratio (4)	lb H_2O/lb steam	14.9	14.9	15.3	16.1	16.3	17.2	13.1	13.9	13.1	18.6	18.0	17.3	18.5	18.8

NOTES:

1. Auxiliary power required for desalination plant based on 275 kw/10^6 gal for 250° F brine heater temperature and 245 kw/10^6 gal for 350° F brine heater temperature and rounded to nearest 10 kw.
2. This electric power is purchased.
3. Performance ratio based on saturated steam at brine heater - not on calculated steam condition.
4. Performance ratio based on calculated steam condition at brine heater.

TABLE 13

CASE NO. →	1, 2 and 3			4			5			6			7, 8 and 9		
REACTOR POWER LEVEL, MWt WATER PRODUCTION, MMGPD STEAM GENERATED, LB/YR BRINE TEMPERATURE, °F	500 50, 35 & 20 13.56×10^9 250			120 19.6 3.25×10^9 250			70 11.6 1.9×10^9 250			40 7.0 1.09×10^3 250			500 50, 35 & 20 13.56×10^9 350		
	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb
1. Depreciating Capital (1)															
a) Reactor Plant	20,360	1,615	11.9	7,963	631	19.4	5,775	458	24.1	4,252	337	30.9	20,360	1,615	11.9
2. Nondepreciating Capital (2)															
a) Land and Land Rights	40	2	Neg	17	1	Neg	13	1	0.1	10	1	0.1	40	2	Neg
b) Working Capital	2,460	142	1.0	607	35	1.1	362	21	1.1	213	12	1.1	2,460	142	1.0
3. Nuclear Liability		178	1.3		124	3.8		103	5.4		81	7.4		178	1.3
4. Subtotal - Fixed Charges		1,937	14.2		791	24.3		583	30.7		431	39.5		1,937	14.3
OPERATING COSTS															
5. Operating and Maintenance		310	2.3		240	7.4		220	11.6		205	18.8		310	2.3
6. Fuel Costs		2,100	15.5		620	19.1		410	21.6		266	24.4		2,10C	15.5
7. Subtotal - Operating Costs		2,410	17.8		860	26.5		630	33.2		471	43.2		2,410	17.8
8. Total - Steam Generation Cost		4,347	32.0		1,651	50.8		1,213	63.9		902	82.7		4,347	32.0

CASE NO. →	10			11			12			13			14		
REACTOR POWER LEVEL, MWt WATER PRODUCTION, MMGPD STEAM GENERATED, LB/YR BRINE TEMPERATURE, °F	120 25.3 3.31×10^9 350			70 14.3 1.93×10^9 350			40 7.8 1.1×10^9 350			40 7.6 1.0×10^9 250			40 8.6 1.1×10^9 350		
	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb	TOTAL CAPITAL COST $\$10^3$	ANNUAL FIXED CHARGES $\$10^3$	UNIT COST ¢/1000 lb
1. Depreciating Capital (1)															
a) Reactor Plant	7,963	631	19.1	5,775	458	23.7	4,252	337	30.6	3,003	238	23.8	3,003	238	21.4
2. Nondepreciating Capital (2)															
a) Land and Land Rights	17	1	Neg	13	1	Neg	10	1	0.1	10	1	0.1	10	1	0.1
b) Working Capital	607	35	1.1	362	21	1.1	213	12	1.1	213	12	1.2	213	12	1.1
3. Nuclear Liability		124	3.7		103	5.3		81	7.4		81	8.1		81	7.3
4. Subtotal - Fixed Charges		791	23.9		583	30.1		431	39.2		332	33.2		332	29.9
OPERATING COSTS															
5. Operating and Maintenance		240	7.3		220	11.4		205	18.6		205	20.5		205	18.4
6. Fuel Costs		620	18.7		410	21.2		266	24.2		266	26.6		266	23.9
7. Subtotal - Operating Costs		860	26.0		630	32.6		471	42.8		471	47.1		471	42.3
8. Total - Steam Generation Cost		1,651	49.9		1,213	62.7		902	82.0		803	80.3		803	72.2

FOOTNOTES:

(1) Amortization Factor
.0793 for Nuclear
.0778 for Fossil-Fired

(2) Amortization Factor
.0580 for Nuclear
.0565 for Fossil-Fired

PARAMETRIC COST STUDIES
SUMMARY OF RESULTS
350°F BRINE TEMPERATURE

TABLE 2

CASE NO. →	7	8	9	10	11	12	14	18-A	18-B	18-C	19-A	19-B	19-C	20-A	20-B	20-C
PLANT TYPE FOSSIL FUEL COST	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL 20¢/10^6Btu	FOSSIL 30¢/10^6Btu	FOSSIL 40¢/10^6Btu	FOSSIL 20¢/10^6Btu	FOSSIL 30¢/10^6Btu	FOSSIL 40¢/10^6Btu	FOSSIL 20¢/10^6Btu	FOSSIL 30¢/10^6Btu	FOSSIL 40¢/10^6Btu
WATER PRODUCTION (MMGPD)	50	35	20	25.3	14.3	7.8	8.6	1	1	1	7	7	7	14	14	14
POWER LEVEL (MWt)	500	500	500	120	70	40	40	6.9	6.4	6.1	45.3	41.4	38.8	82.2	74.5	68.9
*PERFORMANCE RATIO LB WATER/LB STEAM	14.5	14.8	14.0	20.0	19.2	18.6	18.7	13.2	14.2	15.2	14.1	15.5	16.6	15.6	17.3	18.8
CAPITAL COSTS ($1000)																
Steam Plant (Less Land)	20,360	20,360	20,360	7,963	5,775	4,252	3,003	287	275	275	1,422	1,303	1,219	2,203	2,033	1,896
Power Plant	10,460	11,830	13,600	2,317	1,503	900	-	95.7	95.7	95.7	642	642	642	1,112	1,112	1,112
Water Plant	38,515	25,581	14,422	26,515	17,643	12,008	12,811	1,640	1,640	1,640	8,061	8,850	9,640	12,923	15,292	16,872
POWER REQUIREMENTS (MWe)																
Total Power Generated	75.7	101.5	122.5	9.4	5.4	2.9	-	0.29	0.29	0.29	2.0	2.0	2.0	3.90	3.90	3.90
For Water Plant	12.25	8.58	4.9	6.2	3.5	1.9	2.11	0.245	0.245	0.245	1.715	1.715	1.715	3.43	3.43	3.43
For Steam and Turbine Plant	11.92	12.26	12.51	2.71	1.58	0.9	0.1	0.045	0.045	0.045	0.285	0.285	0.285	0.47	0.47	0.47
For By-Product Sale	51.53	80.66	105.09	0.49	0.32	0.1	-	-	-	-	-	-	-	-	-	-
HEAT (10^6Btu/hr)																
Amount to Power Plant	644.7	1005.0	1284.4	32.6	18.2	10.0	-	1	1	1	6.8	6.8	6.8	13.3	13.3	13.3
Amount to Water Plant (Brine Heater)	1066.2	705.9	426.5	377.6	221.6	126.4	136.5	22.6	21.0	19.8	148.2	134.8	125.9	267.9	241.6	222.3
TOTAL	1710.9	1710.9	1710.9	410.2	239.8	136.4	136.5	23.6	22.0	20.8	155.0	141.6	132.7	281.2	254.9	235.6
Percent to Water Plant	62.3	41.3	24.9	92.1	92.9	92.7	100.0	95.8	95.5	95.2	95.6	95.2	94.9	95.3	94.8	94.4
UNIT COSTS																
Steam Price @ Steam Generator (¢/1000 lb)	32.0	32.0	32.0	49.9	62.7	82.0	72.2	52.7	65.3	78.1	38.2	49.4	60.4	35.0	46.4	57.6
Steam Cost to Water Plant (¢/1000 lb)	22.1	22.0	22.0	45.9	57.9	76.0	72.2	50.5	62.4	74.4	36.5	47.0	57.3	33.4	44.0	54.3
Power Generation Cost (mills/kwhr)	7.77	6.84	6.43	12.56	17.29	26.6	-	12.03	12.61	12.67	8.07	8.25	8.76	6.62	6.91	7.43
WATER COSTS (¢/1000 gal)																
Capital	20.9	19.8	19.6	28.5	33.5	41.9	40.5	44.5	44.6	44.6	31.2	34.3	37.4	25.1	28.1	32.7
Operation and Maintenance	8.5	8.3	8.1	10.6	12.2	14.8	13.5	14.7	15.1	15.3	11.1	11.9	12.8	9.6	10.4	11.6
Steam	14.0	13.2	14.0	20.5	26.8	36.7	32.0	33.3	37.8	42.6	22.2	26.3	30.0	18.5	22.1	25.2
Power	4.6	4.0	3.8	7.4	10.2	15.6	4.1	7.1	7.4	7.5	4.8	4.9	5.2	3.9	4.1	4.4
TOTAL	48.0	45.3	45.5	67.0	82.7	109.0	90.1	99.6	104.9	110.0	69.3	77.4	85.4	57.1	64.7	73.9

*Calculated from computer program.

PARAMETRIC COST STUDIES
SUMMARY OF RESULTS
250°F BRINE TEMPERATURE

TABLE 1

CASE NO. ⟶	1	2	3	4	5	6	13	15-A	15-B	15-C	16-A	16-B	16-C	17-A	17-B	17-C
PLANT TYPE FOSSIL FUEL COST	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	NUCLEAR	FOSSIL 20¢/10^6Btu	FOSSIL 30¢/10^6Btu	FOSSIL 40¢/10^6Btu	FOSSIL 20¢/10^6Btu	FOSSIL 30¢/10^6Btu	FOSSIL 40¢/10^6Btu	FOSSIL 20¢/10^6Btu	FOSSIL 30¢/10^6Btu	FOSSIL 40¢/10^6Btu
WATER PRODUCTION (MMGPD)	50	35	20	19.6	11.6	7.0	7.6	1	1	1	7	7	7	14	14	14
POWER LEVEL (MWt)	500	500	500	120	70	40	40	7.3	6.7	6.2	46.8	42.7	39.7	87.5	79.9	74.7
*PERFORMANCE RATIO LB WATER/LB STEAM	14.5	15.1	14.6	17.5	17.9	18.6	19.1	13.5	15.1	16.3	14.9	16.4	17.6	15.9	17.5	18.8
CAPITAL COSTS ($1000)																
Steam Plant (Less Land)	20,360	20,360	20,360	7,963	5,775	4,252	3,003	227	215	202	1,193	1,092	1,012	2,160	1,998	1,869
Power Plant	11,440	12,830	14,440	3,553	2,594	1,604	703	99	99	99	672	672	672	1,184	1,184	1,184
Water Plant	38,577	26,371	15,212	18,528	12,860	9,617	10,424	1,640	1,640	1,640	7,272	8,061	8,850	12,923	14,502	16,082
POWER REQUIREMENTS (MWe)																
Total Power Generated	95.4	113.3	131.3	18	10.6	5.7	2.21	0.3	0.3	0.3	2.100	2.100	2.100	4.2	4.2	4.2
For Water Plant	13.75	9.63	5.5	5.39	3.19	1.93	2.09	0.275	0.275	0.275	1.925	1.925	1.925	3.85	3.85	3.85
For Steam and Turbine Plant	11.88	12.18	12.5	2.78	1.62	0.93	0.12	0.025	0.025	0.025	0.175	0.175	0.175	0.35	0.35	0.35
For By-Product Sale	69.77	91.49	113.3	9.83	5.79	2.84	-	-	-	-	-	-	-	-	-	-
HEAT (10^6Btu/hr)																
Amount to Power Plant	634.6	957.3	1294.1	62.9	36.7	19.8	7.5	1.3	1.3	1.3	7.2	7.2	7.2	14.4	14.4	14.4
Amount to Water Plant (Brine Heater)	1076.3	753.5	416.8	347.4	202.9	116.9	129	24.05	21.85	20.2	152.7	138.7	128.4	284.3	258.2	240.4
TOTAL	1710.9	1710.8	1710.9	410.3	239.6	136.7	136.5	25.35	23.15	21.5	159.9	145.9	135.6	298.7	272.6	254.8
Percent to Water Plant	62.9	44.0	24.4	84.7	84.7	85.5	94.5	94.9	94.4	94.0	95.5	95.1	94.7	95.2	94.7	94.3
UNIT COSTS																
Steam Price @ Steam Generator (¢/1000 lb)	32.0	32.0	32.0	50.8	63.9	82.7	80.3	54.0	68.3	81.3	40.1	52.6	64.7	37.9	50.3	62.5
Steam Cost to Water Plant (¢/1000 lb)	25.8	25.9	25.9	43.4	54.6	71.1	75.9	51.8	65.2	77.4	38.3	50.0	61.3	36.1	47.6	59.0
Power Generation Cost (mills/kwhr)	5.96	5.96	6.03	8.63	11.55	16.78	22.93	10.83	11.35	11.86	7.20	7.60	8.05	6.18	6.50	6.92
WATER COSTS (¢/1000 gal)																
Capital	21.0	20.5	20.7	25.7	30.2	37.4	37.4	44.5	44.6	44.6	28.2	31.3	34.4	25.1	28.1	32.3
Operation and Maintenance	8.5	8.4	8.4	10.1	11.4	13.4	13.8	14.7	15.1	15.4	10.6	11.4	12.2	9.6	10.5	11.4
Steam	14.5	14.5	14.0	22.4	27.9	34.4	34.2	32.5	37.4	41.2	21.9	26.1	29.8	19.3	23.3	26.9
Power	3.9	3.9	4.0	5.7	7.6	11.1	15.1	7.1	7.5	7.8	4.8	5.0	5.3	4.1	4.3	4.6
TOTAL	47.9	47.3	47.1	63.9	77.1	96.4	100.5	98.8	104.6	109.0	65.5	73.8	81.7	58.1	66.2	75.2

*Calculated from computer program based on steam cost at brine heater.